BLM LIBRARY
88064915

Rio Blanco Oil Shale Company

MODULAR DEVELOPMENT PHASE
MONITORING REPORT NINE

Volume 1 of 4

December 1980 – December 1981

Year End Report

OSMIS
LIBRARY CONTROL NO.
02-021-1016

Gulf Oil Corporation / Standard Oil Company (Indiana)
A General Partnership
2851 South Parker Road, Aurora, Colorado 80014

820145S

TN
859
.C64
R56
Dec 80-
Dec 81

RIO BLANCO OIL SHALE COMPANY
MODULAR DEVELOPMENT PHASE
MONITORING REPORT 9

BLM Library
D-553A, Building 50
Denver Federal Center
P. O. Box 25047
Denver, CO 80225-0047

December 1980 - December 1981
YEAR-END REPORT

Prepared by:
RIO BLANCO OIL SHALE COMPANY
AURORA, COLORADO

April 30, 1982

BLM Library
D-553A, Building 50
Denver Federal Center
P. O. Box 25047
Denver, CO 80225-0047

TABLE OF CONTENTS

Section	Title	Page
1	INTRODUCTION	1
2	ATMOSPHERIC STUDIES	
2.0	Introduction	4
2.1	Air Quality	6
2.2	Meteorology	48
2.3	Climatology	80
2.4	Quality Assurance and Data Recovery	89
2.5	Visibility	93
2.6	Noise	112
2.7	Summary	117
3	TERRESTRIAL STUDIES	
3.0	Introduction	121
3.1	Vegetation, Range, and Browse	123
3.2	Fauna	187
3.3	Summary	204
4	AQUATIC STUDIES	
4.0	Introduction	211
4.1	Abiotic Components	215
4.2	Biotic Components	225
4.3	Summary	264
5	HYDROLOGY STUDIES	
5.0	Introduction	268
5.1	Dewatering/Reinjection/Discharge Program	270
5.2	MIS Modular Development Area	295
5.3	Lurgi Plant Site	350
5.4	Summary	371
6	SPECIAL STUDIES/ECOLOGICAL INTERRELATIONSHIPS	
6.0	Introduction	381
6.1	Revegetation	382
6.2	Toxicology	471
6.3	Run-of-Mine Lysimeter	480
6.4	Mule Deer Habitat Modification Study	482
6.5	Shrub Growth Enhancement on a Simulated Mine Site and/or Disposal Pile Bench	490
6.6	Range Exclosure	495
6.7	Supplementary Sulfur Dioxide Monitoring Program	502
6.8	Summary	506
7	SUMMARY	
7.0	Introduction	519
7.1	Air Studies	521
7.2	Terrestrial Studies	524
7.3	Aquatic Studies	530
7.4	Hydrology Studies	532
7.5	Special Studies/Ecological Interrelationships	541

LIST OF APPENDICES

Volume 2

Appendix	Title
2-0	Atmospheric Studies
2-1	Air Quality Data
2-1.1	Gaseous Constituents Data - Sites 1 and 3
2-1.2	Total Suspended Particulate Data - Sites 1, 2, and 3
2-2	Meteorological Data
2-2.1	Meteorological Data - Site 1
2-2.2	Meteorological Data - Sites 2 and 3
2-2.3	Precipitation Data
2-2.4	Snow Depth Data
2-2.5	Barometric Pressure Data
2-6	Visibility Data
2-6.1	Hourly Visual Range Data - Spring 1981
2-6.2	Visibility Site Log Sheets - Spring 1981
2-6.3	Hourly Visual Range Data - Fall 1981
2-6.4	Visibility Site Log Sheets - Fall 1981
3-0	Terrestrial Studies
3-1	Vegetation Data and Analysis
3-1.1	Analyses for Browse Utilization Data
3-1.2	Phytosociological Studies Data
3-1.3	Analyses for Phytosociological Studies Data

LIST OF APPENDICES (Continued)

Volume 2 (Continued)

Appendix	Title
3-1.4	Range Productivity Data
3-1.5	Analyses for Range Production and Utilization Data
3-2	Fauna Data and Analyses
3-2.1	Small Mammal Trapping Results for 1981 by Date, Habitat, Area, Transect and Trap Number
3-2.2	Avifauna Sightings for 1981 by Date, Transect, Habitat and Area
3-2.3	Mule Deer Pellet Group Data for September 1981 and Analysis of Mule Deer Pellet Group Counts May 1978 Through September 1981
3-2.4	Mule Deer Killed by Vehicle Collision Along Rio Blanco County Road 24 During 1979, 1980 and 1981
3-2.5	Feral Horse Observations During 1978, 1979, 1980 and 1981

LIST OF APPENDICES (Continued)

Volume 3

Appendix	Title
4-0	Aquatic Studies
4-1	Abiotic Components Data
4-1.1	Water Quality Data for 1981
4-2	Biotic Components Data and Analyses
4-2.1	Species Composition of Periphyton at Each Station for all Sampling Periods in 1981
4-2.2	Seasonal Changes in Periphyton Species Composition at Each Sampling Station in 1981
4-2.3	Periphyton Enumeration Data for all Stations by Sampling Date for 1981
4-2.4	Periphyton Density and Species Diversity Calculations for all Stations by Sampling Date for 1981
4-2.5	Statistical Analysis of the 1979-1981 RBOSC Periphyton Densities
4-2.6	Taxonomic Composition of Benthic Macroinvertebrates at Each Sampling Station for all Sampling Periods in 1981
4-2.7	Seasonal Changes in Benthic Macroinvertebrate Taxonomic Composition at Each Sampling Station in 1981
4-2.8	Benthic Macroinvertebrate Enumeration Data for all Stations by Sampling Date for 1981
4-2.9	Benthic Macroinvertebrate Density and Diversity Calculations for all Stations by Sampling Date for 1981
4-2.10	Statistical Analysis of the 1979-1981 RBOSC Benthic Macroinvertebrate Densities

LIST OF APPENDICES (Continued)

Volume 3 (Continued)

Appendix	Title
5-0	Hydrology Studies
5-1	Hydrology Monitoring Data Dewatering/Reinjection/Discharge Program
5-1.1	Operations Data for the Dewatering/Reinjection System
5-1.2	Operations Water Quality Data Dewatering/Reinjection/Discharge Program
5-1.3	Springs and Seeps Data Water Quality Data
5-1.4	Upper and Lower Aquifer Field Data Dewatering/Reinjection/Discharge Program
5-1.5	Upper Aquifer Water Quality Data Dewatering/Reinjection/Discharge Program
5-1.6	Multivariate Analysis of Variance (MANOVA) Variance Tests for the Upper Aquifer Water Quality
5-2	Hydrology Monitoring Data MIS Monitoring Program
5-2.1	Operations Field Data for MIS Monitoring Program
5-2.2	Operations Water Quality Data MIS Monitoring Program
5-2.3	Springs and Seeps Data Field Data
5-2.4	Stream Station Field Data MIS Monitoring Program
5-2.5	Alluvial Aquifer Field Data MIS Monitoring Program
5-2.6	Alluvial Aquifer Water Quality Data MIS Monitoring Program

LIST OF APPENDICES (Continued)

Volume 3 (Continued)

Appendix	Title
5-2.7	Multivariate Analysis of Variance (MANOVA) Variance Test Results for Alluvial Water Quality
5-2.8	Upper Aquifer Field Data MIS Monitoring Program
5-2.9	Upper and Lower Aquifer Water Quality Data MIS Monitoring Program
5-2.10	Multivariate Analysis of Variance (MANOVA) Variance Test Results for the Upper Aquifer Water Quality MIS Monitoring Program
5-3	Hydrology Monitoring Data Lurgi Plant Site Program
5-3.1	Hydrology Field Data Lurgi Plant Site Program
5-3.2	Water Quality Data Lurgi Plant Site Program
5-3.3	Multivariate Analysis of Variancw (MANOVA) Variance Tests for the Alluvial and Upper Aquifer Lurgi Plant Site Monitoring Program

LIST OF APPENDICES

Volume 4

Appendix	Title
6-0	Special Studies/Ecological Interrelationships
6-1	Experimental Revegetation Data and Analysis
6-1.1	Plot R-1 Experimental Revegetation Data
6-1.2	Analyses for Plot R-1 Experimental Revegetation Data
6-1.3	Plot R-2 Experimental Revegetation Data
6-1.4	Analyses for Plot R-2 Experimental Revegetation Data
6-1.5	Plot R-3 Experimental Revegetation Data
6-1.6	Analyses for Plot R-3 Experimental Revegetation Data
6-4	Mule Deer Habitat Modification Study
6-4.1	Coverage and Density Data for Mule Deer Habitat Modification Studies
6-4.2	Analyses of Mule Deer Habitat Modification Study Data
6-6	Range Exclosure Data and Analysis
6-6.1	Range Exclosure Cover and Biomass Data
6-6.2	Analyses for Range Exclosure Data

SECTION 1
INTRODUCTION

1.0 INTRODUCTION

The United States Department of the Interior/Geological Survey (USGS) initiated planning in 1969 for a prototype oil shale leasing program. Under this program, Gulf Oil Corporation and Standard Oil Company (Indiana) acquired the rights to Federal Oil Shale Lease Tract C-a in the Piceance Basin in northwest Colorado in 1974. These two companies are developing Tract C-a under a general partnership called the Rio Blanco Oil Shale Company (RBOSC).

RBOSC has been engaged in extensive environmental data collection programs since its inception in 1974. Environmental baseline data were gathered between October 1974 and September 1976. An interim environmental monitoring program was conducted between September 1976 and August 1977, the period during which the Tract C-a lease was suspended. RBOSC initiated the Modular Development Phase (MDP) of tract development and the MDP Environmental Monitoring Program in August of 1977.

The MDP Environmental Monitoring Program is designed to provide data on air quality, meteorology, visibility, terrestrial ecology, aquatic ecology, hydrology, and specialized topics including ecological interrelationships. The program is designed based on the environmental stipulations in the Tract C-a lease, analysis of baseline and interim monitoring data, assessment of probable development impacts, and inputs from the Mineral Management Service Oil Shale Office (OSO). Monitoring is conducted according to the MDP Environmental Monitoring Program Scope of Work (SOW), the current version of which (Revision 6.1) is dated February 25, 1981 and was approved by the OSO May 1, 1981, with four conditions of approval.

Data collected through the MDP Environmental Monitoring Program are reported semi-annually, in a mid-year and a year-end report to the OSO. The first MDP monitoring report (Modular Development Phase Environmental Monitoring Report One or MDP 1) was published in February 1978. Subsequent reports were published in September 1978, March and August 1979, March and August 1980, and March and August 1981. This report is the ninth MDP Monitoring Report (MDP 9), and is the fourth year-end report. The MDP 9 report covers the 1981 reporting year (December 1, 1980-December 31, 1981). The report contains

presentations and summaries of 1981 reporting year data; statistical comparisons between seasons, years, and locations; and assessment of any development-related impacts. Sections of the report generally address objectives, methods, results and discussion, and summary and conclusions. Methods are referenced rather than fully described unless they are different from those employed in previous monitoring periods, need clarification, or have not been previously reported.

Major responsibility for implementation of the MDP monitoring program and preparation of the MDP reports rests with the staff of the RBOSC Environmental Affairs Department. Several other individuals and entities assisted in monitoring activities during the 1981 reporting period and in preparation of MDP 9, however. They include the following:

Morrison-Knudsen and The Industrial Company (TIC) (Operational Hydrology Monitoring)
Mariah Associates (Aquatic Ecology Sample Analysis and Report Preparation)
U.S. Geological Survey (Surface Water Gaging Station Data)
Dr. J. S. Warner (Statistical Review)
Cathedral Bluffs Shale Oil Company (Visibility Monitoring)

Volume one of MDP 9 contains the following major sections:

Section 1	Introduction
Section 2	Atmospheric Studies
Section 3	Terrestrial Studies
Section 4	Aquatic Studies
Section 5	Hydrology Studies
Section 6	Special Studies/Ecological Interrelationships
Section 7	Summary

Volumes two through four of MDP 9 contain the following appendices:

Appendix 2-1	Air Quality Data
Appendix 2-2	Meteorological Data
Appendix 2-5	Visibility Data
Appendix 3-1	Vegetation Data and Analyses
Appendix 3-2	Fauna Data and Analyses
Appendix 4-1	Aquatic Abiotic Data and Analyses
Appendix 4-2	Aquatic Biotic Data and Analyses
Appendix 5-1	Dewatering/Reinjection/Discharge Hydrological Data and Analyses
Appendix 5-2	MIS Modular Development Area Hydrological Data and Analyses
Appendix 5-3	Lurgi Site Hydrological Data and Analyses
Appendix 6-1	Experimental Revegetation Data and Analyses
Appendix 6-4	Mule Deer Habitat Modification Data and Analyses
Appendix 6-6	Range Exclosure Data and Analysis

SECTION 2
ATMOSPHERIC STUDIES

2.0 INTRODUCTION

The Tract C-a atmospheric studies program consists of two elements: (1) measurements of total suspended particulate matter and certain gaseous chemical compounds, and (2) measurements of selected meteorological parameters. The monitoring locations were originally established to measure the ambient air quality generally upwind and somewhat removed from the expected tract development, and at points where tract developments might have an effect on the air quality. Simultaneous meteorological measurements are being made to allow for the prediction of the dispersion of emissions resulting from tract development.

Air quality and meteorological data have been obtained since February 1975 from monitoring instruments located on or near Tract C-a. Data collected during the first two years of monitoring make up the baseline data set. Data from the baseline period were obtained at four locations around the tract. Following the baseline period, an interim data acquisition program was established to cover an interval during which the tract development lease conditions were modified and partially suspended. During the interim period (February through August 1977), a single air quality and meteorological monitoring station was operated to maintain data continuity.

The current air studies program is part of the Modular Development Phase (MDP) Environmental Monitoring Program. The level of activity on the tract, principally construction work and the burning of two prototype MIS retorts, has increased significantly during the MDP period. The monitoring program has been expanded in order to measure possible effects of increased tract activity on the ambient air quality. Two of the sites that had been deactivated for the interim period were refitted with meteorological instrumentation and put back on-line during the first quarter of the MDP. In addition, one of the reactivated meteorological sites has been refitted with a complete set of air quality instrumentation (Table 2-1).

Table 2-1. Air Studies Monitoring Parameters and MDP Program Schedule, Tract C-a

Parameter	Location	Start Date	Frequency
Sulfur Dioxide	Site 1	Sept. 1977	Continuously
	Site 3	Jan. 1978	Continuously
Nitrogen Oxides	Site 1	Sept. 1977	Continuously
	Site 3	Feb. 1980	Continuously
Nitric Oxide	Site 1	Sept. 1977	Continuously
	Site 3	Feb. 1980	Continuously
Hydrogen Sulfide	Site 1	Nov. 1977	Continuously
	Site 3	Jan. 1978	Continuously
Carbon Monoxide	Site 1	Oct. 1977	Continuously
	Site 3	Nov. 1979	Continuously
Hydrocarbons(1)	Site 1	Sept. 1977	Continuously
Ozone	Site 1	Sept. 1977	Continuously
	Site 3	Nov. 1977	Continuously
Particulates	Sites 1, 2, 3	Dec. 1977	Every 3rd day
	Site 6[1/]	Dec. 1977	Every 3rd day
Wind direction (10m)	Sites 1, 2, 3	Sept. 1977	Continuously
Wind direction (60m)	Site 1	Sept. 1977	Continuously
Wind speed (10m)	Sites 1, 2, 3	Sept. 1977	Continuously
Wind speed (60m)	Site 1	Sept. 1977	Continuously
Wind sigma	Sites 1, 2, 3	Sept. 1980	Continuously
Ambient temperature (10m)	Sites 1, 2, 3	Sept. 1977	Continuously
Temperature differential (10-60m)	Site 1	Sept. 1977	Continuously
Precipitation	Sites 1, 2, 3 & other selected locations	Oct. 1977	By event
Snow depth and accumulation	Sites 1, 2, 3	Nov. 1978	By event
Solar radiation	Site 1	Sept. 1977	Continuously
Dewpoint (10m)	Site 1	July 1978	Continuously
Visibility	Visibility Shelter	Spring 1978	Semi-annually
Noise	16 locations on tract	Jan. 1978	Quarterly

[1/] Discontinued by agreement with OSO.

2.1 AIR QUALITY

Air quality monitoring is being conducted on and near Tract C-a to measure the concentrations of certain pollutants which may be emitted by tract operations. The ambient air quality monitoring network consists of two locations where gaseous constituents are measured (Sites 1 and 3) and three locations where total suspended particulate (TSP) concentrations are measured (Sites 1, 2, and 3). Sites 1 and 2 are located to measure background ambient air quality, while Site 3 is located in a broad gulch that may have some air quality changes due to downvalley flow of pollutants from the main development area in the center of the tract.

All of the air quality data, with the exception of the TSP data, is collected by automatic monitoring equipment and recorded by a data acquisition system on digital computer tape and backup strip charts. The data on the digital tape are averaged into hourly values. High volume samplers are used to collect 24-hour samples of TSP concentrations every third day.

A cooperative visibility study (with Tract C-b) has been conducted each spring and fall since 1978 as part of the air studies program. In 1979, an addition was made to the study by measuring the visual range with a telephotometer as well as with the traditional photometric technique. This addition will allow comparisons to be made between the two measurement techniques.

Starting early in 1980, analyzers to monitor carbon monoxide and oxides of nitrogen were re-installed at Site 3 and included in the data acquisition system. There is now a full complement of operational air quality analyzers at both Sites 1 and 3 (Table 2-1).

Air quality data collected during the most recent six-month period (the sixteenth and seventeenth quarters of the MDP program) are presented in Appendices 2-1.1 (gaseous constituents) and 2-1.2 (total suspended particulates).

As part of the year-end report, an extensive analysis has been carried out on the data obtained during the most recent four quarters of the MDP program. The "MDP year" has been changed with this report from a December-November reporting period to a standard calendar year. In order to make this transition, the air studies data contained in Volume 2 of this report cover the seven-month period from June to December, 1981. Consequently, beginning with this report, all data summaries and tables will be computed based upon the twelve-month calendar year (the present reporting period, January-December 1981, will hereafter be referred to in this report as the current year). In order to improve consistency, most of the tables which include previous data years for comparison have been recomputed on a calendar-year basis. Comparisons have been made among the current year, the baseline period (February 1975-January 1977), and the three previous years of the MDP period (January-December 1978, January-December 1979, and January-December 1980).

When analyzing a data set, it is important to evaluate the data in relation to the limitations of the instrumentation. This is particularly true of air quality data gathered in a pristine environment such as Tract C-a. Ambient concentrations of several gaseous constituents usually are at or below the minimum measurement capability of air quality monitoring instruments. Statistical analyses may therefore not be applicable to these data sets.

A quantitative measure has been developed to use as a conservative minimum level, below which there is essentially no probability that the values represent real and valid data. This level, called the threshold of detection, is defined as twice the noise level of the instrument. The threshold of detection can thus be used to determine if there is a sufficient number of valid data points to warrant further statistical analyses.

It should be emphasized that the threshold of detection is a conservative measure to use in determining data validity. It is designed to take into account the errors or uncertainties which develop when measurements are taken near the minimum detectable limit of any monitor. These uncertainties are extremely difficult to quantify, but it is quite likely that the threshold of detection as defined above represents the instruments and data acquisition system in an optimal condition. Consequently, this value, determined independently for each instrument, is a conservative measure of data validity.

That is, some data that are not significant (within the noise of the measurement system) may be retained, but no valid data will be arbitrarily discarded (due to a detection limit set too high).

The ultimate goal is to define confidence limits around the data collected by each instrument, which will serve as realistic criteria with which to judge the validity of the data. Threshold of detection values for each instrument are given in Table 2-2. These detection limits can be used as a guide to determine how much of the data can be considered valid for statistical analysis. The significance of the data for each parameter will be discussed separately in the appropriate sections below. In several instances, the data sets are at or below the minimum detectable limit of the instrument, which limits the analysis that can be applied to the data.

A. Sulfur Dioxide

1. Objectives

The objective of monitoring for sulfur dioxide is to establish the ambient air concentration prior to and during tract development. The existing sulfur dioxide levels and associated environmental effects can be used as a basis for assessing future environmental changes that may be related to any increase in the concentration of sulfur dioxide.

2. Methods

The methods followed for collection of sulfur dioxide data were described in RBOSC MDP Monitoring Report 5 (RBOSC 1980).

3. Results and Discussion

Table 2-3 provides mean, maximum, and minimum concentrations of air quality parameters monitored at Tract C-a during the current year. The table shows that maximum concentrations of sulfur dioxide were 0.047 ppm at Site 1 and 0.014 ppm at Site 3, while mean concentrations were 0.003 ppm at both sites. Most of the sulfur dioxide concentrations monitored during the current year were at or below the threshold of detection for the instruments.

Table 2-2. Air Quality Instrumentation used at Tract C-a, with the Threshold of Detection for each Monitor

Parameter	Manufacturer	Model	Technique	Threshold of Detection (ppm)
SO_2	Thermo Electron Corporation	43	Pulsed Fluorescence	0.002
H_2S	Thermo Electron Corporation	45	Pulsed Fluorescence	0.002
NO/NO_x	Bendix	8101-B	Chemiluminescence	0.005
Photochemical Oxidant (O_3)	Bendix	8002	Chemiluminescence	0.001
CO	Bendix	8501-5CA	Nondispersive infrared detection	0.5

Table 2-3. Summary of Air Quality Data Collected Between January and December 1981, Tract C-a

Parameter	Units	Minimum[1/]	Maximum[1/]	Arithmetic Mean
		Site 1		
O_3	ppm	0.012	0.070	0.043
CO	ppm	0.5	1.0	0.5
NO	ppm	0.005	0.061	0.005
NO_x	ppm	0.005	0.039	0.005
H_2S	ppm	0.002	0.015	0.004
SO_2	ppm	0.002	0.047	0.003
TSP[3/]	$\mu g/m^3$	1	44	15.[2/]
		Site 2		
TSP[3/]	$\mu g/m^3$	1	54	15.[2/]
		Site 3		
O_3	ppm	0.001	0.073	0.029
CO	ppm	0.5	1.0	0.5
NO	ppm	0.005	0.027	0.005
NO_x	ppm	0.005	0.043	0.005
H_2S	ppm	0.002	0.015	0.004
SO_2	ppm	0.002	0.014	0.003
TSP[3/]	$\mu g/m^3$	2	73	21.[2/]

[1/] Hourly average.

[2/] Geometric Mean.

[3/] 24-hour averages.

The highest sulfur dioxide concentration recorded during the curent year, 0.047 ppm at Site 1 on September 4 at 0800 hours, probably resulted from sulfur dioxide emissions during the burning of Retort 1. This conclusion is based upon a review of the wind direction data at Site 1, which show an easterly wind from 0700 to 1000 hours, which would transport the stack emissions westward to Site 1. On a number of mornings during the burn of Retort 1 (June-December 1981), sulfur dioxide concentrations slightly higher than background ambient levels were detected for a short period when easterly upslope winds were present (see Section 2.2, Meteorology, for a further discussion of this phenomenon).

A unique opportunity to study the impacts of releasing fairly large amounts of sulfur dioxide (up to 1,000 lbs/hr) from the process site came in late September and October of this year, when emergency repairs to the main stack necessitated venting the retort off-gas to the flare stack. A supplemental monitoring program was set up to better define the sulfur dioxide plume by using grab bag samples (a report on this special study is included in Section 6.7). The main conclusion from this study was that even at emission rates of up to 7 times the allowable limit in the PSD permit (138 lb/hr), no NAAQS or state standard was in danger of being violated. In addition, the highest instantaneous measurement of sulfur dioxide (260 $\mu g/m^3$) was only about one-half of the 3-hr Class II PSD increment of 512 $\mu g/m^3$. A large amount of spatial and temporal variability was noted in the sulfur dioxide concentrations monitored during this special study. No elevated sulfur dioxide concentrations were detectable to the east of the tract at Site 3 (in Corral Gulch) during the Retort 1 burn.

Comparison of the current year's data (Table 2-3) with data from earlier years (January-December 1980, Table 2-4; February 1975 - January 1977, Table 2-5) show that yearly maximum and average sulfur dioxide concentrations have been similar in each of the years. The maximum hourly sulfur dioxide concentration in 1981 (0.047 ppm at Site 1) was caused by emissions from Retort 1, in 1980, the maximum concentration (0.036 ppm at Site 1) was caused by emissions from Retort 0; during the baseline period, the maximum concentration (0.09 ppm) was at least partially the result of less accurate and sophisticated instrumentation. The yearly means during both the baseline and MDP periods have been at or below the threshold of detection of the monitoring equipment.

Table 2-4. Summary of Air Quality Data Collected Between January and December 1980, Tract C-a

Parameter	Units	Minimum[1]	Maximum[1]	Arithmetic Mean
		Site 1		
O_3	ppm	0.013	0.077	0.045
CO	ppm	0.5	0.9	0.5
NO	ppm	0.005	0.061	0.005
NO_x	ppm	0.005	0.062	0.005
H_2S	ppm	0.002	0.013	0.003
SO_2	ppm	0.002	0.036	0.002
TSP[3]	$\mu g/m^3$	2	61	13.[2]
		Site 2		
TSP[3]	$\mu g/m^3$	1	61	12.[2]
		Site 3		
O_3	ppm	0.003	0.070	0.034
CO	ppm	0.5	0.5	0.5
NO	ppm	.005	.024	.005
NO_x	ppm	.005	.028	.005
H_2S	ppm	0.002	0.060	0.004
SO_2	ppm	0.002	0.013	0.003
TSP[3]	$\mu g/m^3$	1	96	18.[2]

[1] Hourly Average.

[2] Geometric Mean.

[3] 24-hour Averages.

Table 2-5. Summary of Air Quality Data Collected Between February 1975 and January 1977 (Baseline), Tract C-a

Parameter	Units	Minimum(2)	Maximum(2)	Arithmetic Mean
		Site 1		
O_3	ppm	0.000	0.068	0.034
CO	ppm	0.000	4.2	0.6
NO	ppm	0.000	0.237	0.008
NO_x	ppm	0.000	0.234	0.009
H_2S	ppm	0.000	0.05	0.01
SO_2	ppm	0.000	0.09	0.01
TSP[3/]	$\mu g/m^3$	1	211	9[2/]
		Site 2		
TSP[3/]	$\mu g/m^3$	1	102	9[3/]
		Site 3		
O_3	ppm	0.000	0.089	0.031
CO	ppm	0.000	6.0	0.6
NO	ppm	0.000	0.159	0.006
NO_x	ppm	0.000	0.154	0.006
H_2S	ppm	0.000	0.03	0.01
SO_2	ppm	0.000	0.05	0.01
TSP[3/]	$\mu g/m^3$	1	281	15[2/]

[1/] Hourly Average.

[2/] Geometric Mean.

[3/] 24-hour Average.

B. Hydrogen Sulfide

1. Objectives

The objective of monitoring hydrogen sulfide in the ambient air on the tract is to establish the background value. Tract development, which will involve recovery of sulfur-bearing organics, may release hydrogen sulfide into the ambient air. Future concentrations of this constituent may be compared to pre-development conditions to assess environmental impacts.

2. Methods

The methods for collection of hydrogen sulfide data were described in RBOSC MDP Monitoring Report 5 (RBOSC 1980).

3. Results and Discussion

Table 2-3 shows that maximum concentrations of hydrogen sulfide during the current year were 0.015 ppm at both Sites 1 and 3. Annual mean concentrations were 0.004 ppm at both sites.

Comparisons with previous data show that the mean annual concentrations have remained at or below the threshold of detection for the entire study period. Compared to the baseline period, marginally higher maximum hydrogen sulfide concentrations have occurred at Site 3 during the MDP. This may be related to the surface flow in Corral Gulch past Site 3, which is partially made up of of groundwater discharge containing reduced sulfur compounds.

C. Oxides of Nitrogen

1. Objectives

Oxides of nitrogen are monitored to establish the existing natural background levels prior to major tract development and operation. Tract operations will involve substantial combustion during the retorting process with the resultant generation of oxides of nitrogen. Nitric oxide in the presence of sunlight and hydrocarbons may be a mechanism for smog production.

2. Methods

The methods followed for collection of oxides of nitrogen data were described in MDP Monitoring Report 2 (RBOSC 1978A).

3. Results and Discussion

As the concentrations of both nitric oxide and oxides of nitrogen were below the threshold of detection most of the time during the current year, the 1981 annual mean of both these variables at Site 1 is at or below 0.005 ppm. These values are similar to those obtained during previous years--no annual mean for either nitric oxide or oxides of nitrogen exceeded 0.01 ppm. The maximum concentrations measured during the current year were 0.061 ppm for nitric oxide and 0.039 ppm for oxides of nitrogen. These maximum values were measured before Retort 1 was ignited, and thus could not be caused by emissions from the retort. The most likely cause of these slightly elevated concenterations was activity associated with oil and gas drilling in the area.

The mean concentrations of nitric oxide and oxides of nitrogen measured during the current year at Site 3 were both 0.005 ppm. The maximum concentrations were 0.027 ppm for nitric oxide and 0.043 ppm for oxides of nitrogen. As noted above these maximum values could not have been caused by emissions from Retort 1.

D. Carbon Monoxide

Carbon monoxide is produced by incomplete oxidation of carbon during combustion. Vehicular use and fuel combustion during tract development may result in the emission of carbon monoxide in the tract area.

1. Objectives

Carbon monoxide is monitored to establish the ambient air concentration of this constituent prior to and during tract development activities.

2. Methods

The methods followed for collection of carbon monoxide data were described in MDP Monitoring Report 2 (RBOSC 1978A).

3. Results and Discussion

At both Sites 1 and 3, the measured concentration of carbon monoxide was at or below the threshold of detection most of the time. Maximum concentrations of carbon monoxide at both were 1.0 ppm. The mean concentrations of carbon monoxide at both sites were 0.5 ppm. These concentrations are very similar to those measured in earlier years.

E. Ozone

1. Objectives

Ozone monitoring is conducted to determine the ambient air concentration of this constituent prior to and during tract development and operation. The potential emissions of oxides of nitrogen coupled with hydrocarbons in strong sunlight can produce photochemical reactions leading to the formation of ozone.

2. Methods

The methods followed for collection of ozone data were described in RBOSC MDP Monitoring Report 2 (RBOSC 1978A).

3. Results and Discussion

The range of ozone concentrations recorded during the current year, as shown in Table 2-3, was 0.012 to 0.070 ppm at Site 1 and 0.001 to 0.073 ppm at Site 3. The mean concentration of ozone at Site 1 was 0.043 ppm and at Site 3 was 0.029 ppm. Thus, there were no violations of the primary or secondary National Ambient Air Quality Standard (NAAQS) for ozone (0.12 ppm) at either site. These concentrations are comparable to those found during the previous monitoring periods (Tables 2-4 and 2-5).

In addition to the difference in magnitude of mean ozone concentrations between Site 1 and Site 3, there is also a difference in the distribution of ozone concentrations between the two sites. As illustrated in Figures 2-1 through 2-5, there is a diurnal cycle of mean hourly ozone concentrations at both sites. Although Sites 1 and 3 both show a maximum ozone concentration during the day and a minimum at night, the average diurnal change is much smaller at Site 1 (0.007 ppm at Site 1 vs. 0.022 ppm at Site 3).

Figures 2-6 through 2-10 are histograms of the hourly ozone concentrations at both sites during each of the four seasons and for the entire year. The ozone concentrations are shown in 0.01 ppm increments. Site 1 shows a fairly narrow distribution of concentration during each season, with a shift to higher concentrations during the spring and summer. Site 3, on the other hand, shows a much broader distribution of ozone concentrations, but with the same shift to high concentrations during the warm seasons. This ozone peak during the summer is a common phenomenon (U.S. EPA 1978). These histograms are another way of illustrating the pronounced diurnal variations of ozone concentrations typical of Site 3 and the relatively constant concentrations typical of Site 1.

Three previous year-end reports (RBOSC MDP Monitoring Reports 3, 5 and 7; RBOSC 1979, 1980, and 1981, respectively) discussed this diurnal ozone cycle at Sites 1 and 3. The conclusion was that the peak daytime ozone concentrations at both sites were similar because of the efficient mixing of the boundary layer due to atmospheric turbulence. However, at night a strong surface-based inversion very often develops over the gulch in which Site 3 is located, effectively isolating Site 3 from the elevated pool of relatively ozone-rich air. This allows surface destruction reactions to reduce the ambient concentration of ozone in the gulch during the night. Since Site 1 is near the top of a hill rather than in a gulch, it is not often trapped within a strong surface inversion, and consequently does not have a mechanism to significantly reduce the ozone concentrations at night.

The other phenomenon discussed during the earlier year-end reports was the relatively high concentrations of ozone measured at such a remote site as Tract C-a. The conclusion, based on an analysis of the site data and research done at other rural sites, was that these relatively high concentrations may be due to a number of factors, including stratospheric injection, photochemical

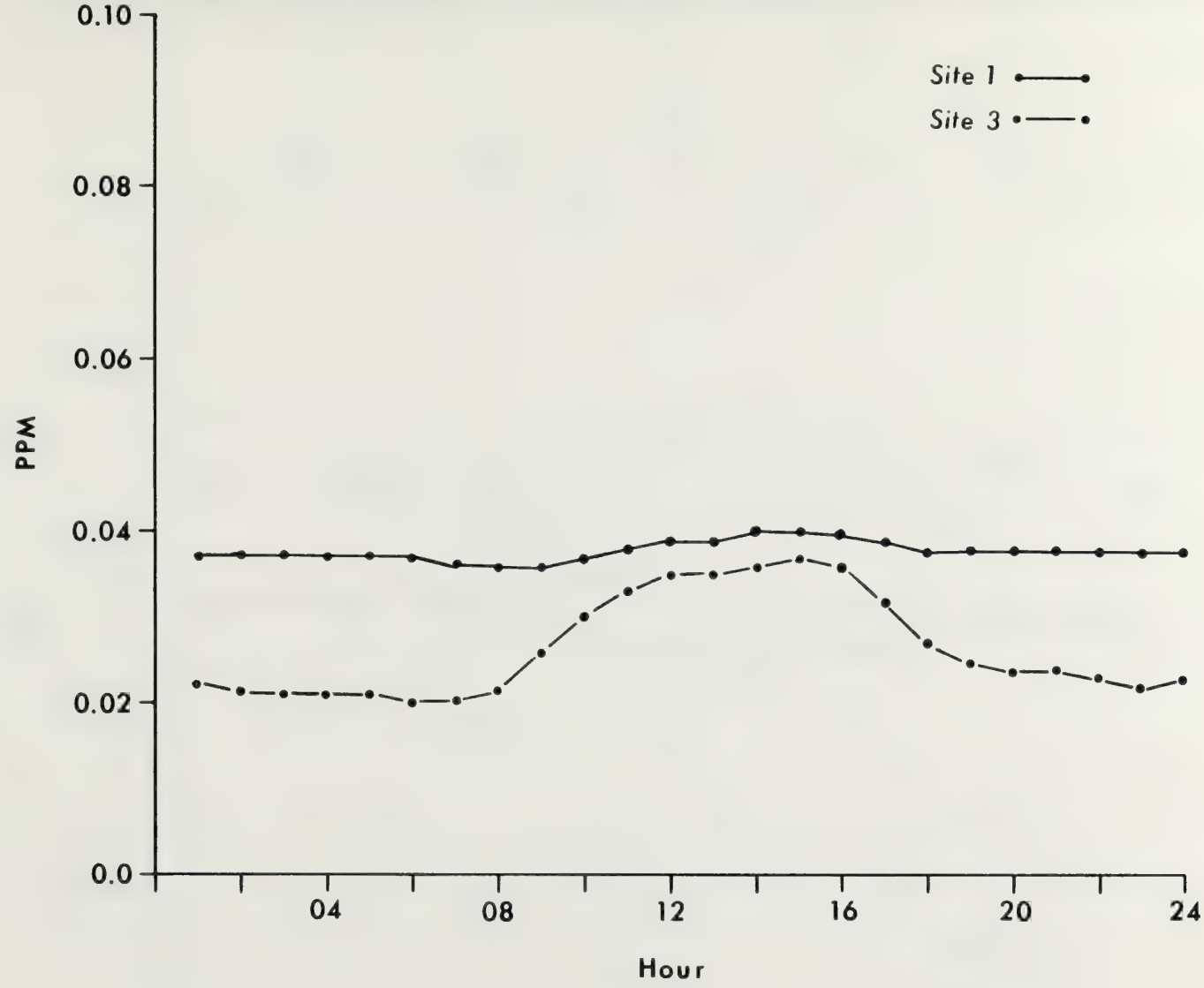


Figure 2-1. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Winter (Jan, Feb, Dec 1981), Tract C-a

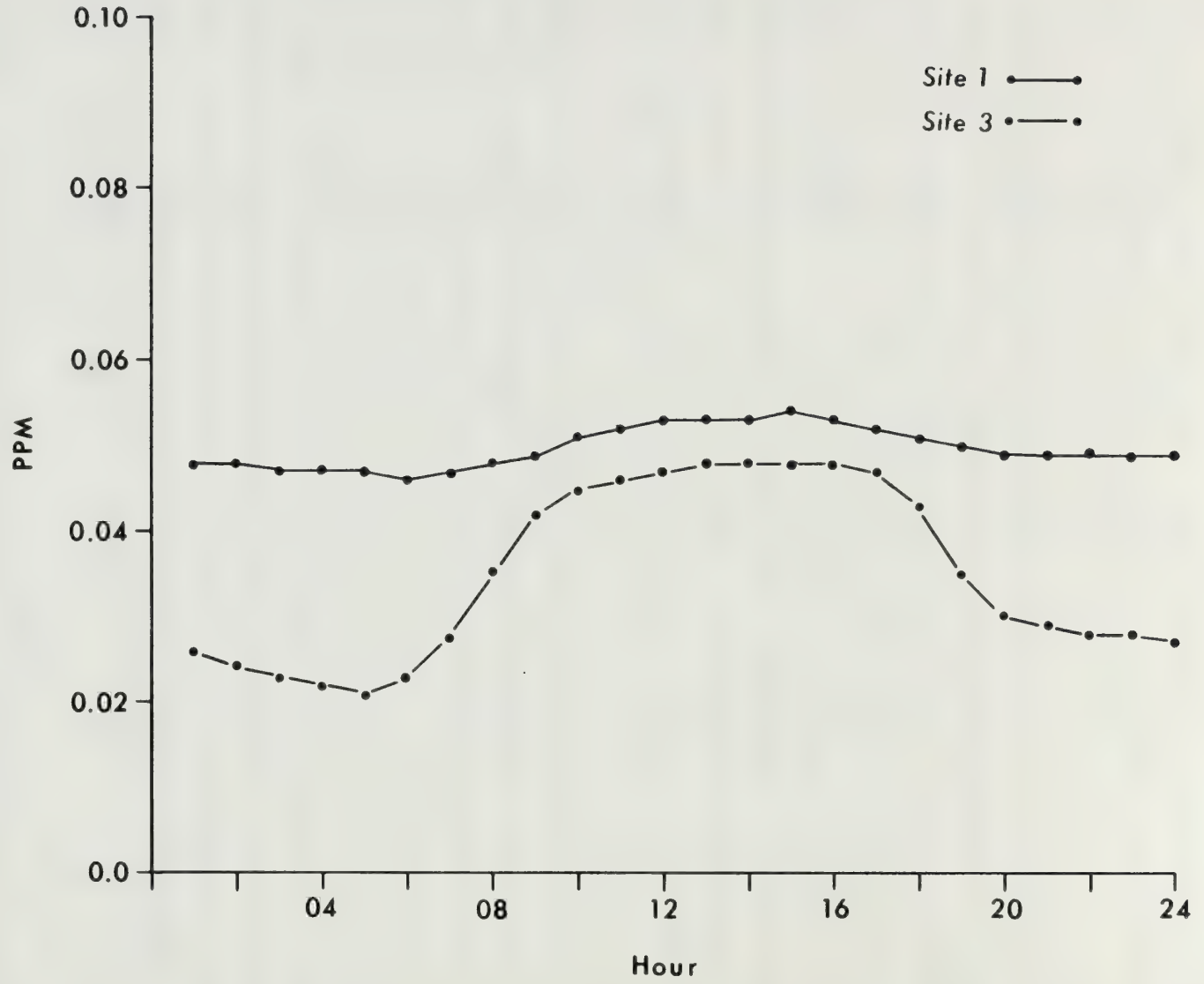


Figure 2-2. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Spring (Mar-May 1981), Tract C-a

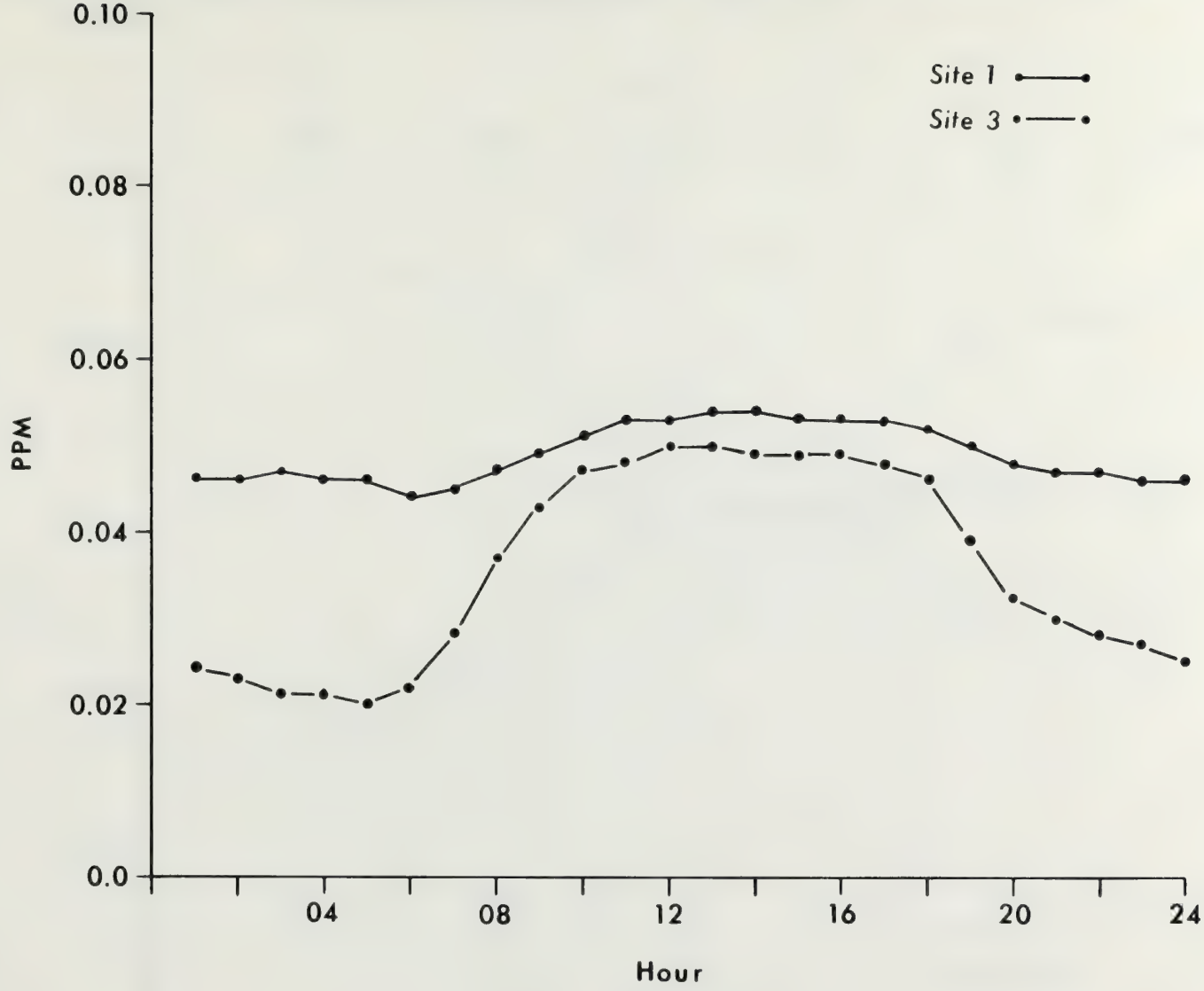


Figure 2-3. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Summer (Jun-Aug 1981), Tract C-a

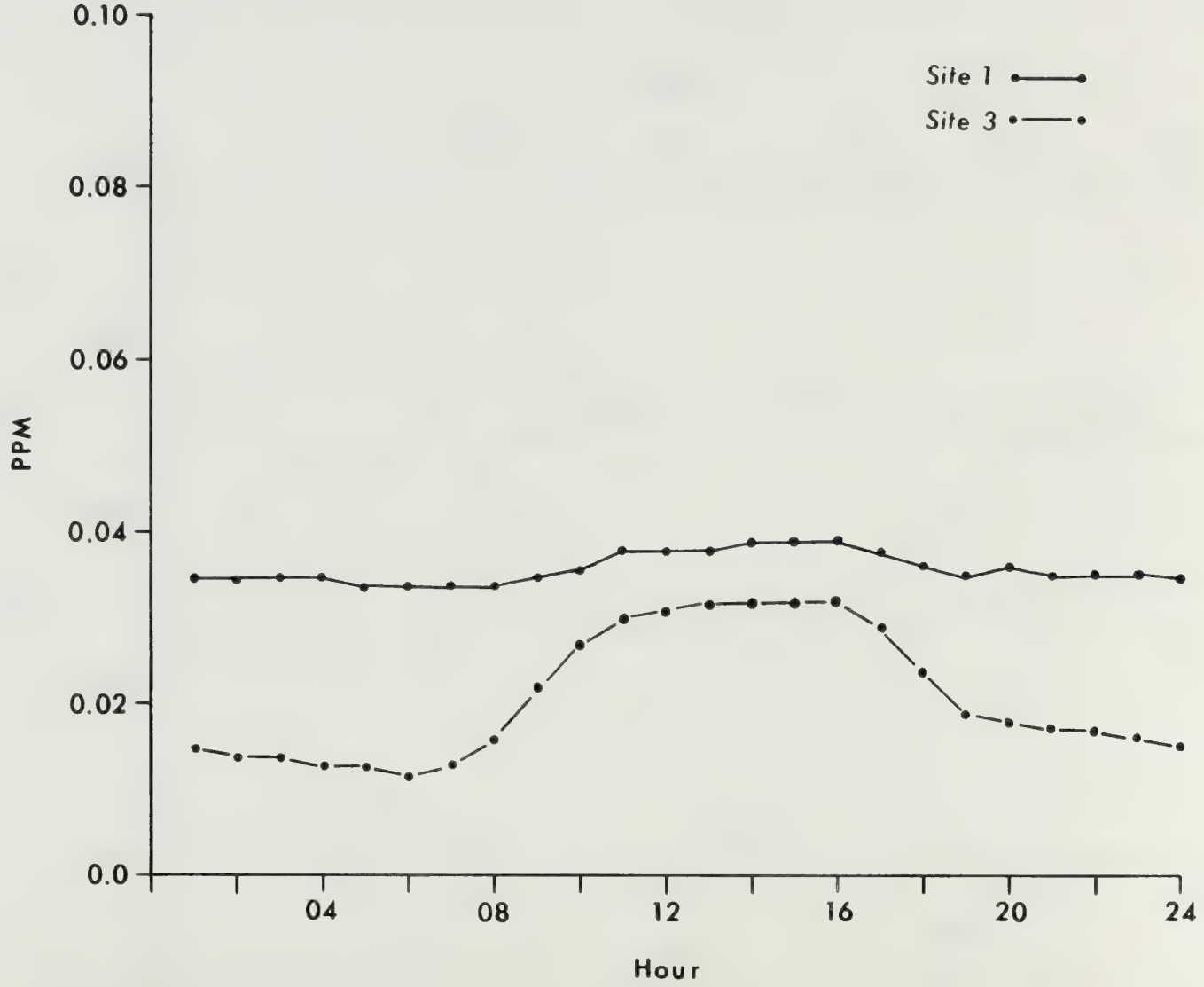


Figure 2-4. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Fall (Sep-Nov 1981), Tract C-a

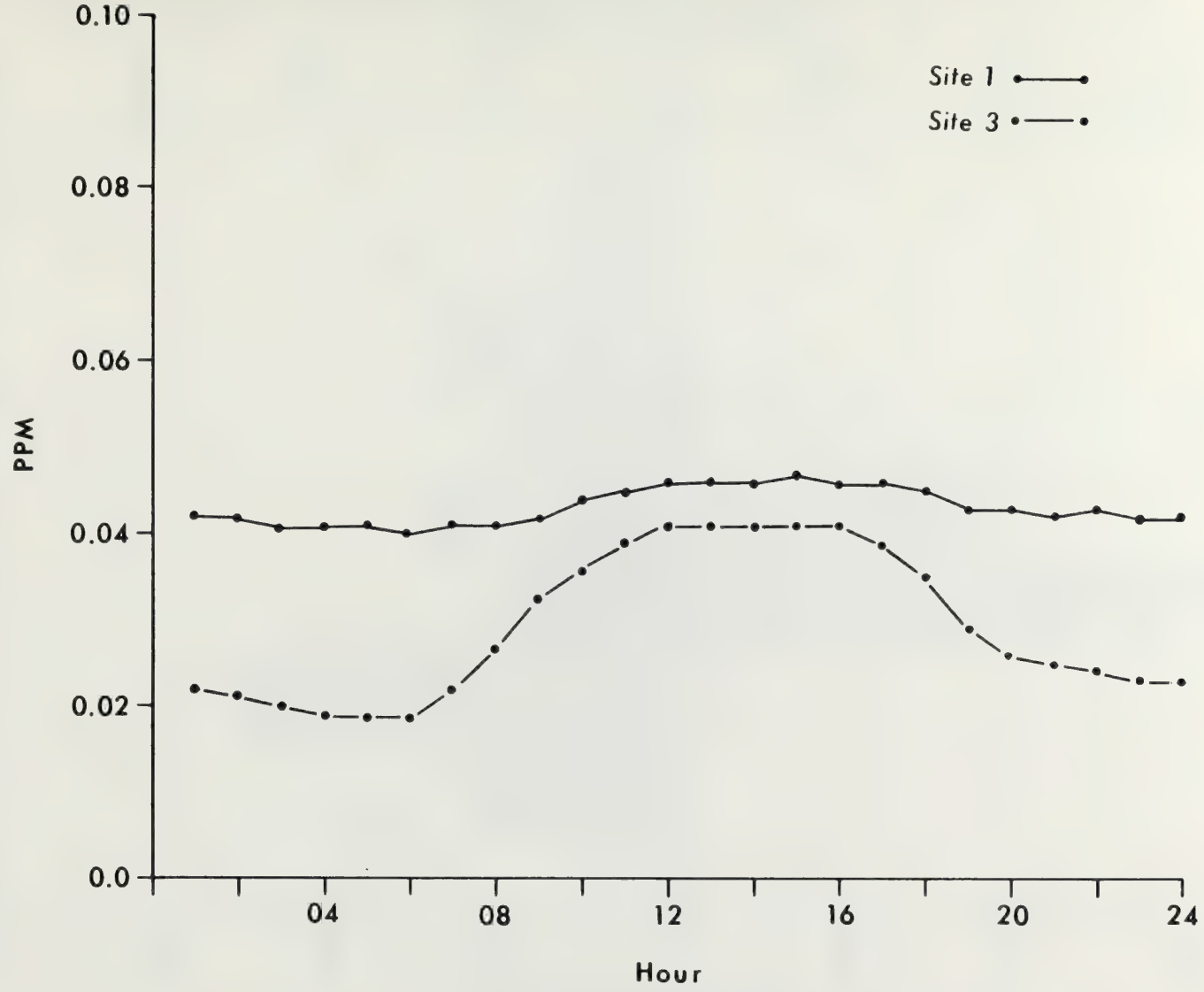


Figure 2-5 Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Annual Average (Jan-Dec 1981), Tract C-a

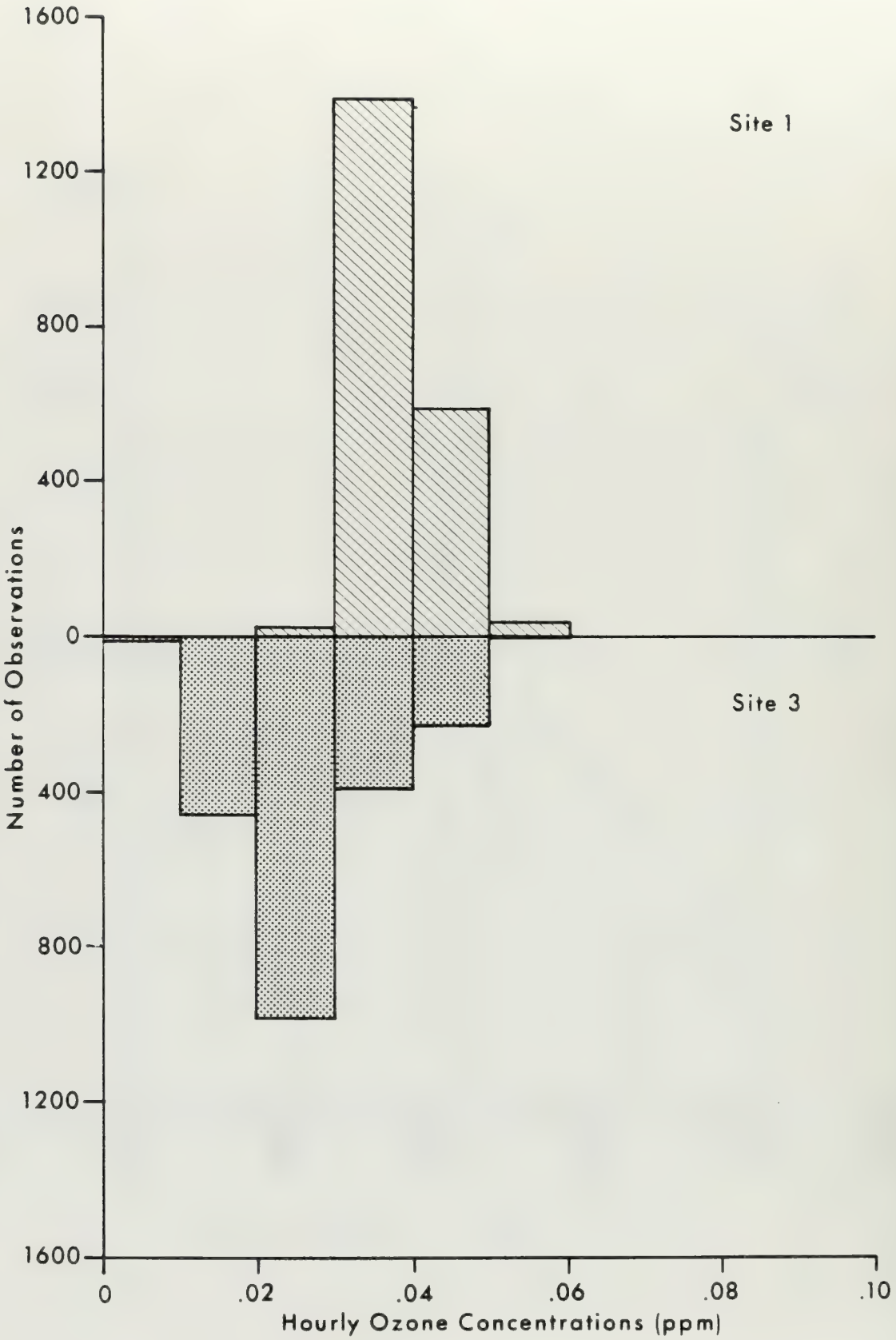


Figure 2-6. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Winter (Jan., Feb., Dec. 1981), Tract C-a

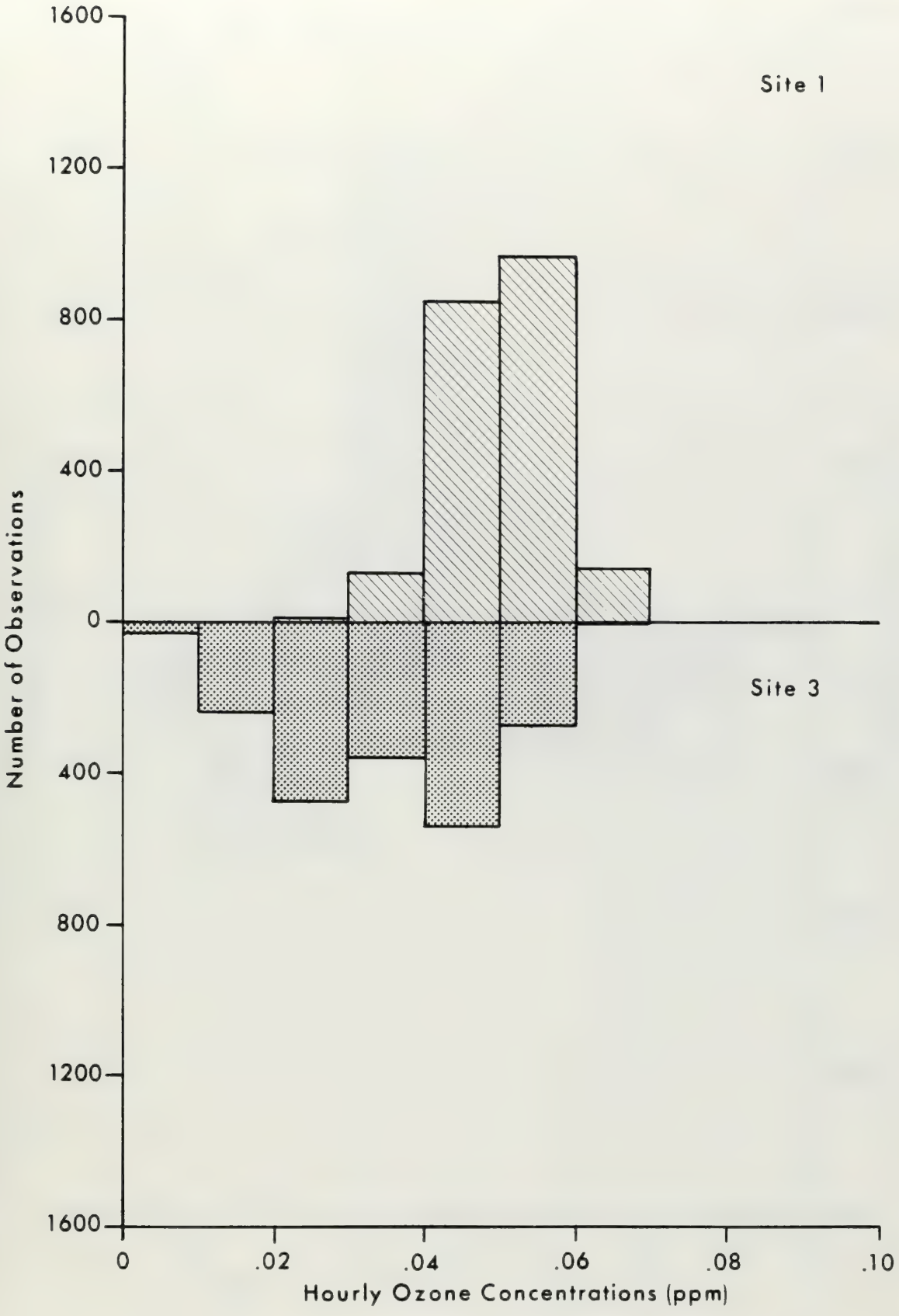


Figure 2-7. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Spring (Mar.—May 1981), Tract C-a

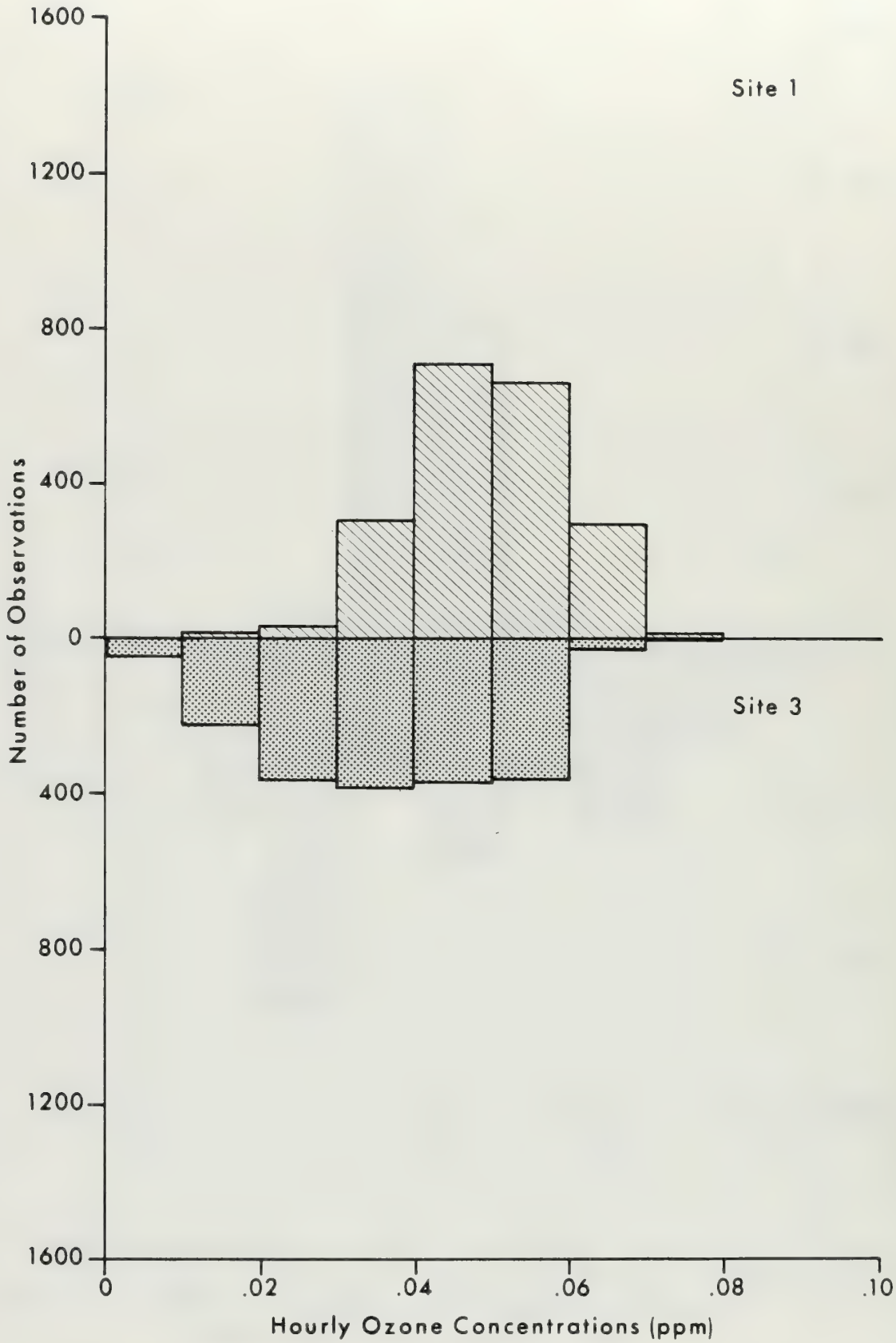


Figure 2-8. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Summer (Jun.—Aug. 1981), Tract C-a

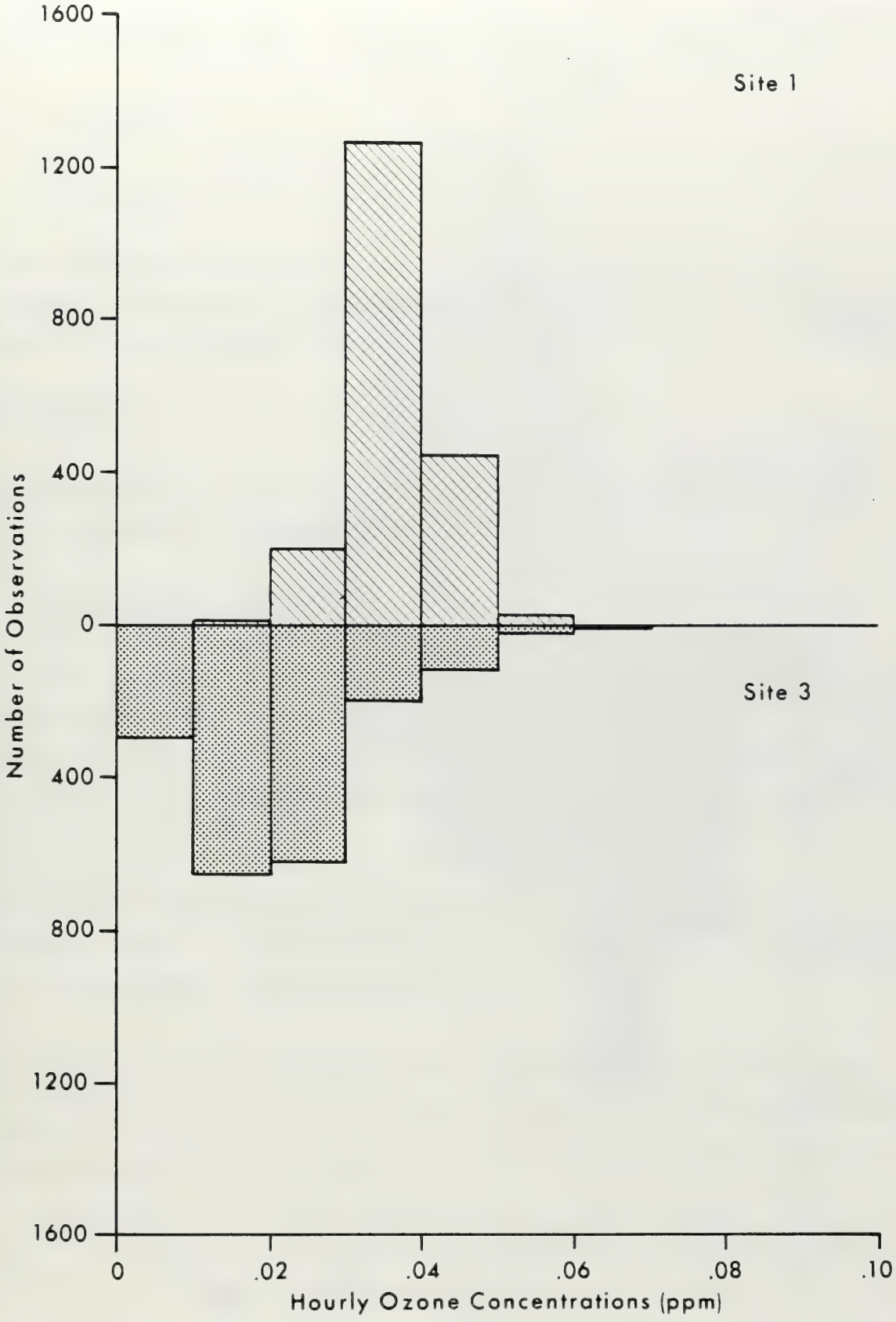


Figure 2-9. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Fall (Sep.—Nov. 1981), Tract C-a

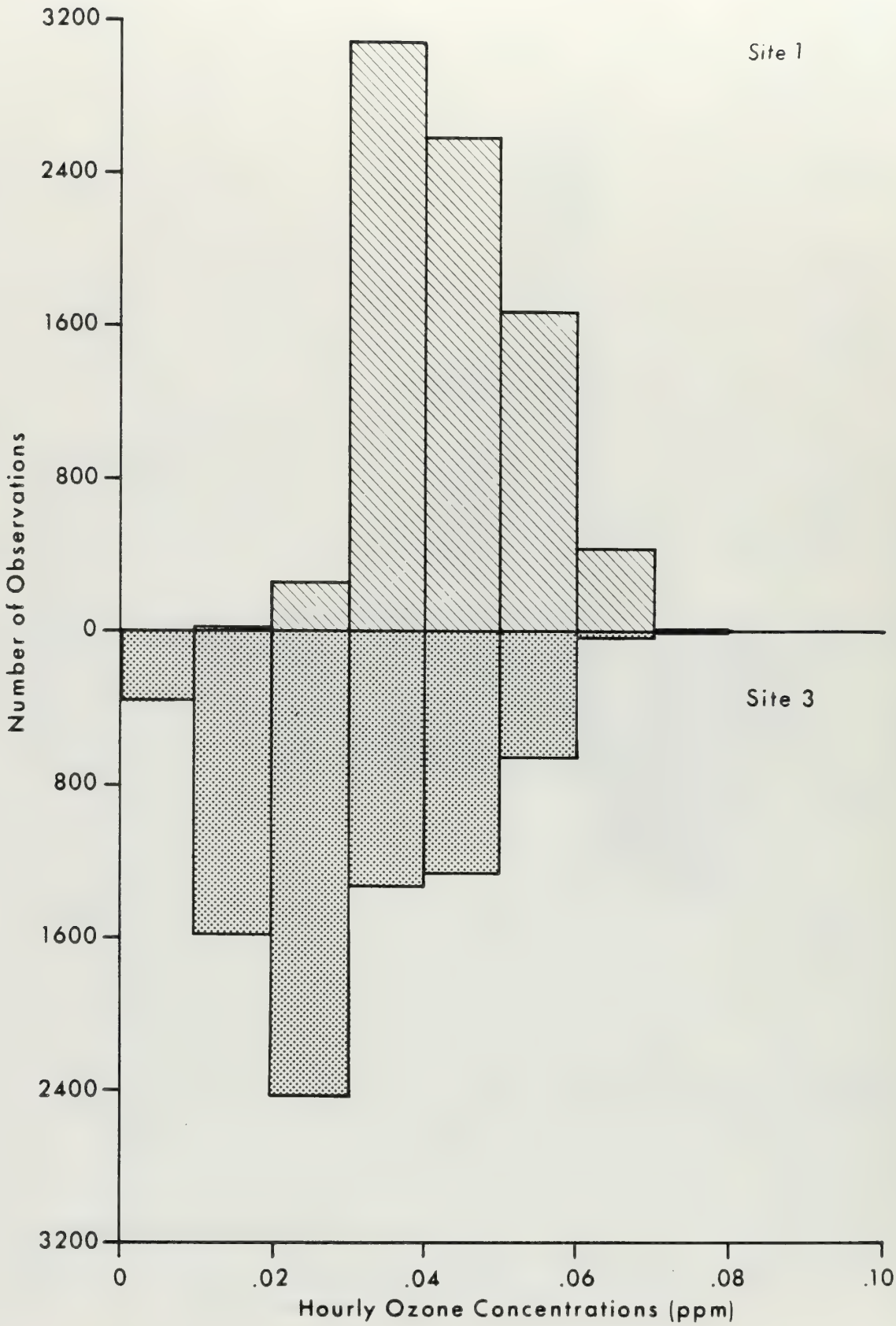


Figure 2-10. Histogram of Hourly Ozone Concentrations (ppm) at Sites 1 and 3, Annual 1981, Tract C-a

reactions, or long-range transport. The concept of local production of ozone as an important factor has not been supported by the observed events.

F. Particulates

1. Objectives

The objectives of total suspended particulate (TSP) monitoring are to establish a natural background TSP concentration and to monitor the effects on TSP concentrations of development of the tract.

2. Methods

The methods followed for collection of TSP data were described in MDP Monitoring Report 4 (RBOSC 1979A).

3. Results and Discussion

Quarterly and annual geometric mean and maximum values of the TSP data for the current year at each of the three sites are presented in Table 2-6. The highest maximum concentration, 73 $\mu g/m^3$, was measured during the summer quarter at Site 3. This value is well below the National Ambient Air Quality Standard (NAAQS) for TSP of 160 $\mu g/m^3$.

The highest quarterly geometric means and 24-hour TSP concentrations occurred during the summer. The lowest values occurred during the winter, when there was a semipermanent snowcover on the tract.

The quarterly and annual geometric means and maximum TSP concentrations of 1980 and the baseline period are presented in Tables 2-7 and 2-8, respectively. Comparison of Tables 2-6 and 2-7 shows that the geometric mean annual TSP concentrations for Sites 1 and 2, which are located generally upwind of the tract development areas, have been relatively constant during the last two years. The mean annual TSP concentrations at these two sites have ranged between 12 and 15 $\mu g/m^3$. These means are somewhat higher than those for the baseline period at Sites 1 and 2 (Table 2-8), when mean concentrations

Table 2-6. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average Total Suspended Particulate Concentrations from January to December 1981 ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3
Winter 1981 (Jan, Feb, Dec)			
Geometric Mean	9	9	15
Maximum	25	25	48
Spring 1981 (Mar-May)			
Geometric Mean	16	15	21
Maximum	41	44	42
Summer 1981 (Jun-Aug)			
Geometric Mean	25	26	38
Maximum	44	49	73
Fall 1981 (Sep-Nov)			
Geometric Mean	14	13	17
Maximum	39	54	54
1981 Annual			
Geometric Mean	15	15	21
Maximum	44	54	73

Table 2-7. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average Total Suspended Particulate Concentrations from January to December 1980 ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3
Winter 1980 (Jan, Feb, Dec)			
Geometric Mean	7	6	9
Maximum	17	20	36
Spring 1980 (Mar-May)			
Geometric Mean	11	12	14
Maximum	36	42	51
Summer 1980 (Jun-Aug)			
Geometric Mean	29	21	43
Maximum	61	51	96
Fall 1980 (Sep-Nov)			
Geometric Mean	16	15	26
Maximum	56	61	76
1980 Annual			
Geometric Mean	14	12	19
Maximum	61	61	96

Table 2-8. Quarterly and Annual Geometric Means and Maximum Values of 24-Hour Average Total Suspended Particulate Concentrations for the Baseline Period (February 1975 to January 1977) ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3
February 1975			
Geometric Mean	--	3	5
Maximum	--	10	12
Spring 1975 (Mar-May)			
Geometric Mean	29	11	23
Maximum	95	84	163
Summer 1975 (Jun-Aug)			
Geometric Mean	22	15	47
Maximum	211	95	247
Fall 1975 (Sep-Nov)			
Geometric Mean	6	16	18
Maximum	52	102	137
Winter 1975-76 (Dec-Feb)			
Geometric Mean	2	2	4
Maximum	10	11	14
Spring 1976 (Mar-May)			
Geometric Mean	11	11	11
Maximum	80	51	130
Summer 1976 (Jun-Aug)			
Geometric Mean	22	22	27
Maximum	81	57	105
Fall 1976 (Sep-Nov)			
Geometric Mean	12	15	35
Maximum	53	46	281
Winter 1976-77 (Dec-Jan)			
Geometric Mean	5	6	5
Maximum	18	57	59
1975-76 Annual			
Geometric Mean	9	9	18
Maximum	211	102	247
1976-77 Annual			
Geometric Mean	8	9	12
Maximum	81	57	281

ranged from 8 to 9 $\mu g/m^3$. This could reflect either changing meteorological conditions or increased offsite activity (e.g., oil and gas drilling).

The geometric mean annual TSP concentrations at Site 3, located generally downwind of the tract development areas, have always been considerably higher than Sites 1 or 2. During 1980 and 1981, the concentrations have been 19 and 21 $\mu g/m^3$, respectively, which compares with concentrations during the two baseline years of 12 and 18 $\mu g/m^3$.

The tables illustrate that there is a seasonal difference in the ratio of monitored TSP concentrations between Site 3 and the other two sites: during the winter and the spring seasons, the geometric mean TSP concentrations at all three sites are very similar, while during the summer, the Site 3 mean is considerably higher than Sites 1 and 2. This is reasonable, since the winter snowcover should reduce the localized impacts on individual sites. High fugitive dust emissions during the dry summer from tract development or other activities, on the other hand, should have the greatest impact at Site 3.

The annual cumulative frequency distributions of the TSP concentrations at each of the three sites are presented in Figure 2-11. The distributions for Sites 1 and 2 are similar. The figure shows that the 50 percent probability point for the TSP concentrations are 17 $\mu g/m^3$ for Site 1, 16 $\mu g/m^3$ for Site 2, and 24 $\mu g/m^3$ for Site 3. These compare reasonably well with values obtained in 1980 of 13 $\mu g/m^3$, 13 $\mu g/m^3$, and 16 $\mu g/m^3$ for the same sites, respectively. The 50 percent probability concentrations obtained for the baseline period, 10 $\mu g/m^3$ for Site 1, 12 $\mu g/m^3$ for Site 2, and 22 $\mu g/m^3$ for Site 3, also agree well with both of these data sets from the MDP (RBOSP 1976).

a. Correlation analysis - One of the reasons for conducting this analysis is to evaluate the factors affecting the seasonal differences in the TSP concentrations. As discussed above, it is quite possible that a variety of physical processes and mechanisms may affect the data during different times of the year. In particular, during winter, the semi-permanent snowcover should reduce the impacts of localized particulate sources (i.e., the main tract

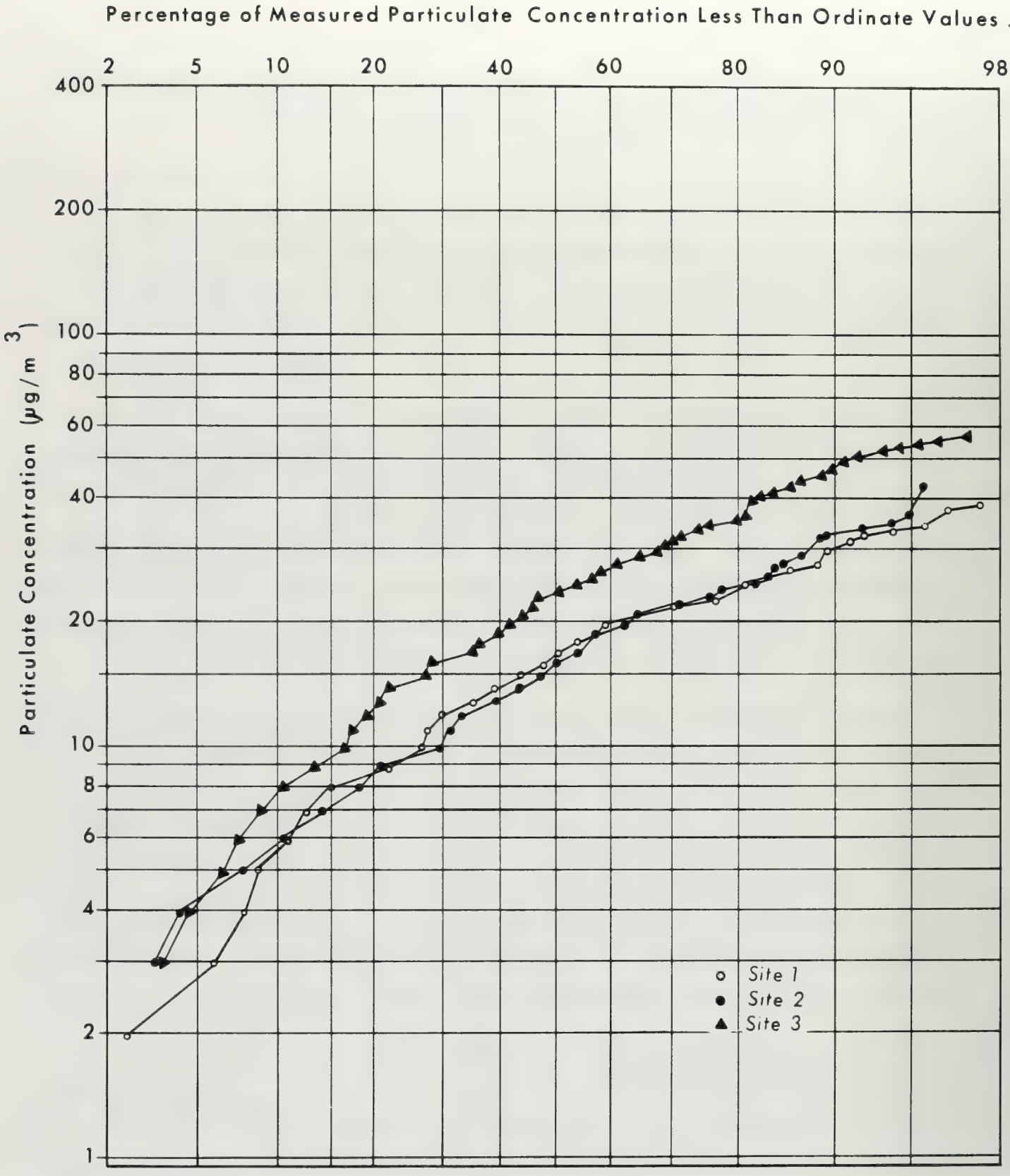


Figure 2-11. Cumulative Frequency Distributions of Total Suspended Particulate Da
from the Three Tract C-a Monitoring Sites, Jan.-Dec. 1981

access road near Site 3, or the pipeline right of way adjacent to Site 1), such that the sites are influenced more by general regional sources. Thus, particulate concentrations among sites might be expected to be more highly correlated during the winter than during the summer. Figures 2-12 through 2-14, which present the separate cumulative distributions for the winter and summer seasons, indicate that the cumulative distributions for each site can be subdivided into the two seasons with minimum overlap.

Table 2-9 presents the correlations of the particulate concentrations among the three sites for each of the four years of record. The correlations are given for the entire data year, the summer season (defined for purposes of this analysis as the period within each data year during which snowcover was absent), and the winter season (defined as the period within each data year during which snowcover was present). Because of the year-to-year variability in meteorological factors, the length of the two seasons varied considerably. Based on snow depth and precipitation records, the summer season for each year was determined to be:

Baseline:	1975-76	April 11 - October 23, 1975
	1976-77	March 30 - December 1, 1976
MDP:	1979	April 14 - October 28, 1979
	1980	April 13 - October 13, 1980
	1981	April 8 - October 26, 1981

The period before and after the summer season of each year was taken to be the winter season.

The correlations (r) for 1980 and 1981 presented in Table 2-9 are quite high for all sites. The coefficient of determination (r^2) given in the table shows that over the past two years, an average of 75 percent of the annual variation in TSP concentration at Site 1 is associated with the variation at Site 2 (r^2_{12}). This indicates that both sites, which are generally upwind of tract activities, are primarily affected by regional rather than localized influences. The r^2 values between the two sites are nearly as high for the separate summer and winter seasons.

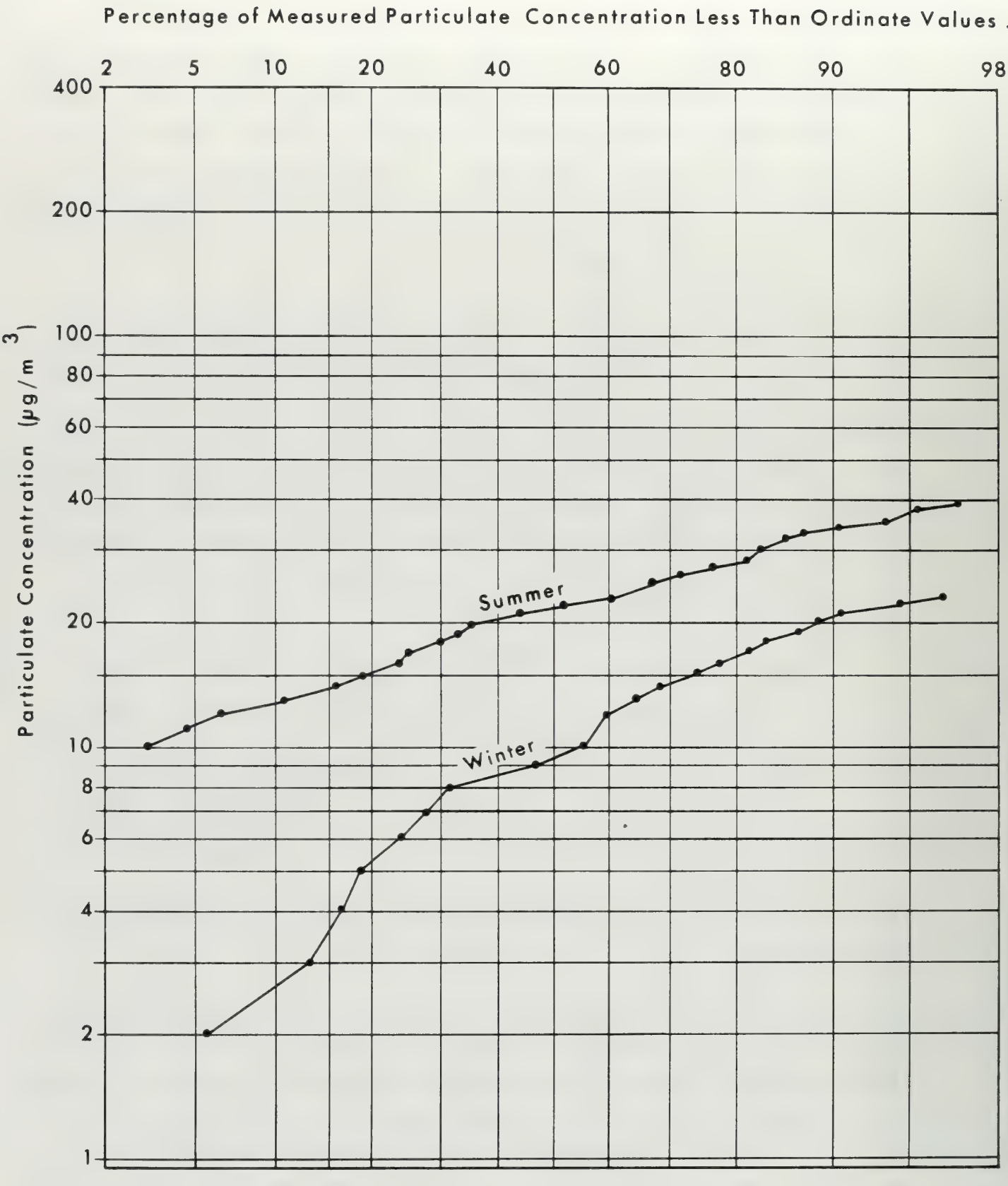


Figure 2-12. Cumulative Frequency Distributions of Total Suspended Particulate Data from Site 1 During the 1981 Summer and Winter Seasons, Tract C-a

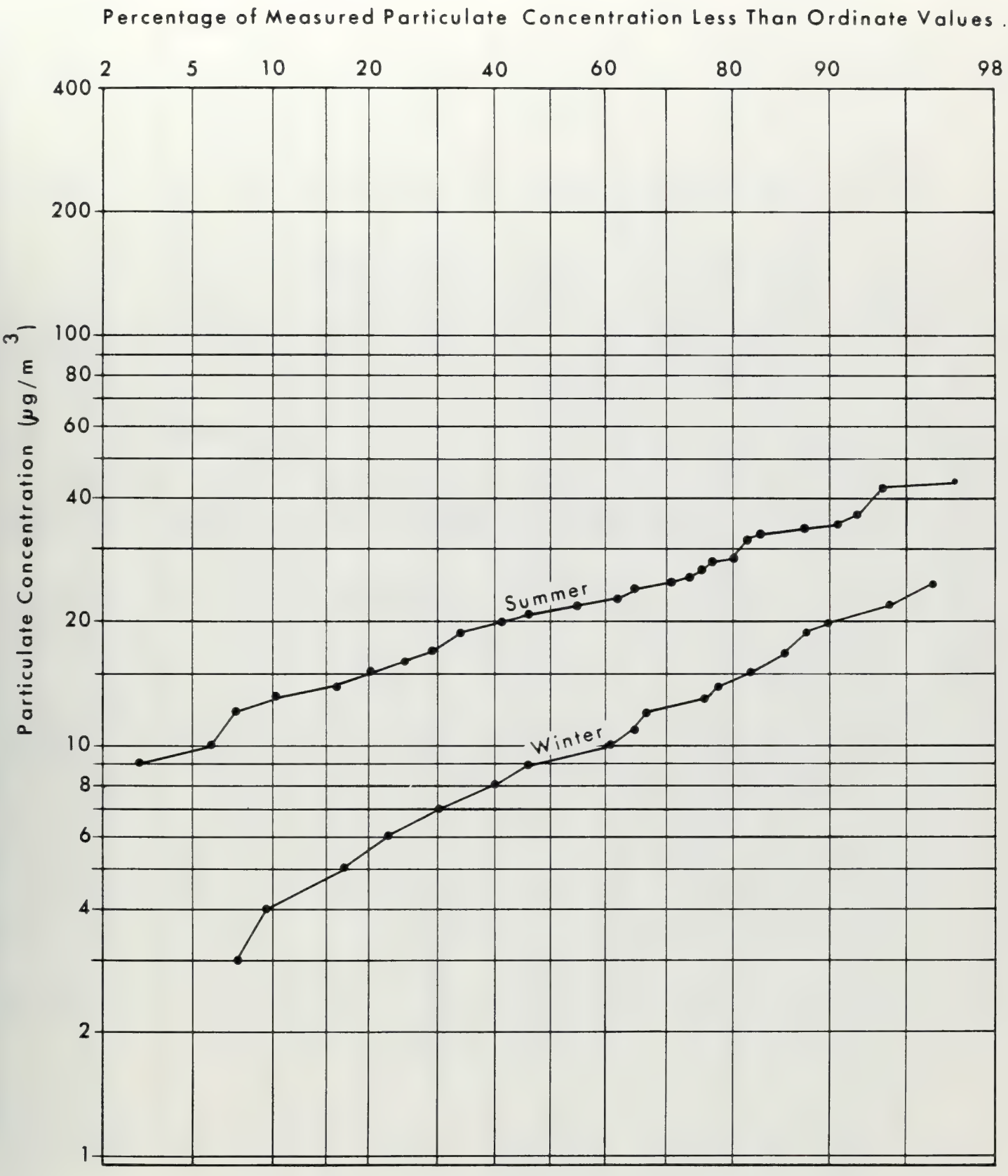


Figure 2-13. Cumulative Frequency Distributions of Total Suspended Particulate Data from Site 2 During the 1981 Summer and Winter Seasons, Tract C-a

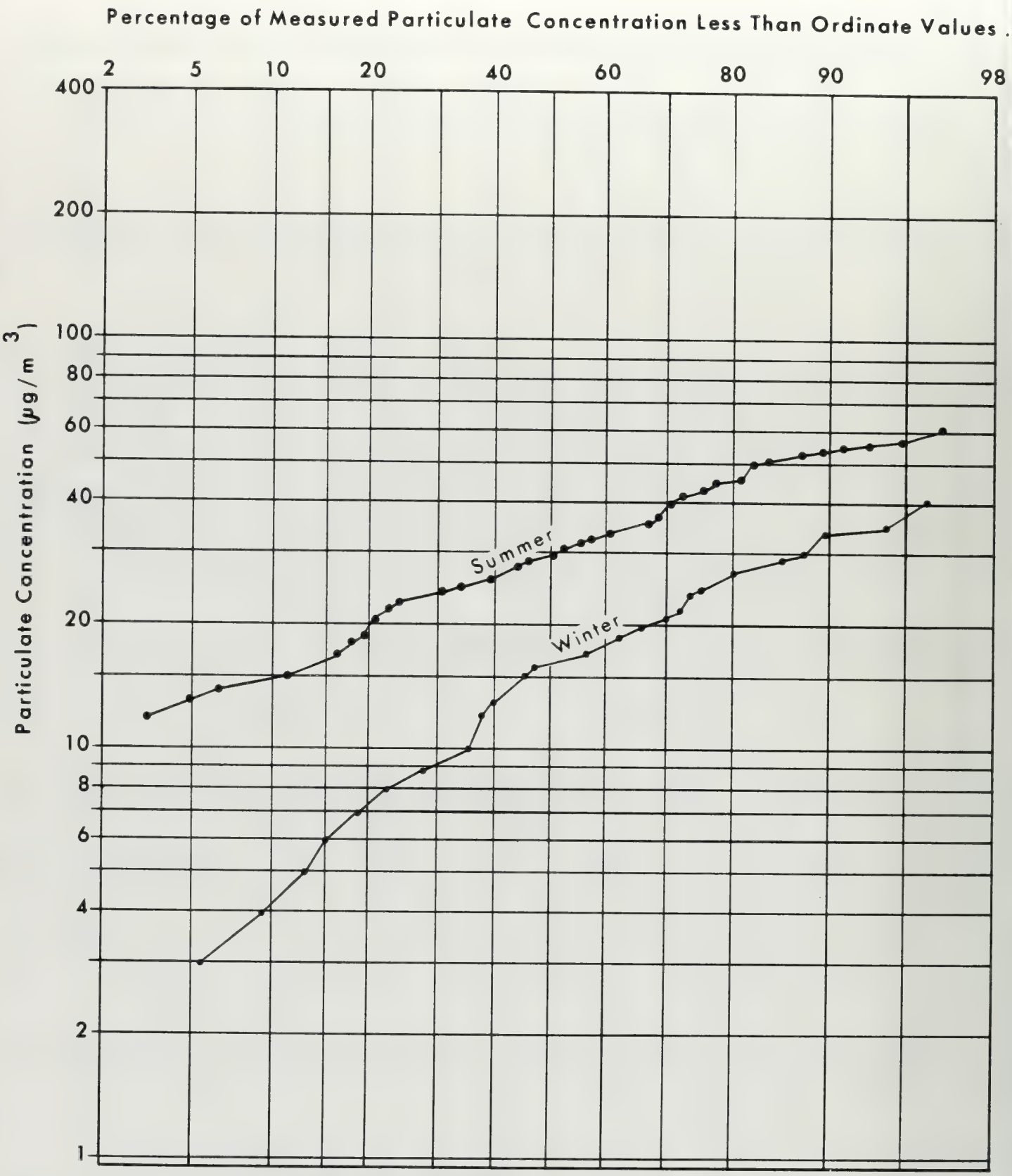


Figure 2-14. Cumulative Frequency Distributions of Total Suspended Particulate Data from Site 3 During the 1981 Summer and Winter Seasons, Tract C-a

Table 2-9. Correlation Coefficients (r), Coefficients of Determination (r^2), and Sample Number (N) for the 24-hour Average Total Suspended Particulate Concentrations at Sites 1, 2, and 3, Tract C-a

Correlation	Baseline (2/75 - 1/76) r	r^2	N	Baseline (2/76 - 1/77) r	r^2	N	Modular Development Phase (1979) r	r^2	N	(1980) r	r^2	N	(1981) r	r^2	N
For Total Year															
Sites 1 vs 2	0.53	0.28	91	0.63	0.40	91	0.57	0.33	115	0.86	0.74	114	0.88	0.77	115
Sites 1 vs 3	0.31	0.10	89	0.49	0.24	114	0.60	0.36	115	0.83	0.69	113	0.85	0.72	108
Sites 2 vs 3	0.56	0.32	105	0.47	0.22	72	0.71	0.50	108	0.76	0.58	110	0.77	0.60	109
For Summer Only															
Sites 1 vs 2	0.43	0.19	59	0.57	0.33	53	0.46	0.22	62	0.80	0.63	60	0.86	0.74	63
Sites 1 vs 3	0.14[1/]	0.02	57	0.43	0.18	86	0.44	0.19	60	0.76	0.58	60	0.79	0.62	56
Sites 2 vs 3	0.40	0.16	63	0.36	0.13	42	0.54	0.29	58	0.64	0.41	58	0.73	0.54	59
For Winter Only															
Sites 1 vs 2	0.17[1/]	0.03	32	0.36	0.13	38	0.81	0.65	53	0.82	0.67	54	0.76	0.57	52
Sites 1 vs 3	0.16[1/]	0.03	32	0.23[1/]	0.05	28	0.59	0.35	55	0.57	0.33	53	0.80	0.65	52
Sites 2 vs 3	0.73	0.53	42	0.47	0.22	30	0.73	0.54	50	0.56	0.31	52	0.57	0.33	50

[1/] These correlations are not significantly different than zero at $\alpha = 0.05$.

When Site 3 (the downwind site) data for 1981 are compared with Site 1 and Site 2 data for 1981, the annual TSP correlation drops off somewhat: r^2_{13} is 0.72 and r^2_{23} is 0.60. Similar results were obtained through analysis of 1980 data. Thus, the TSP data for either upwind site and the downwind site are still highly correlated, although not quite as well as the two upwind sites.

The correlations during 1979 are much lower; on an annual basis r^2_{12} is 0.33, r^2_{13} is 0.36, and r^2_{23} is 0.50. There are two possible reasons for this: (1) The main tract access road, which passes within 100 yards of Site 3, was paved in mid-1979, thereby reducing a major localized fugitive dust source; and (2) an underground natural gas pipeline was installed in the fall of 1979 within 25 yards of Site 1, which resulted in a large temporary source of fugitive dust at that site. Table 2-9 shows that the correlations during the baseline period are also low in comparison with the MDP period. No explanation for this behavior is currently available.

Table 2-10 shows the results of a different type of correlation: whereas Table 2-9 presents the correlations between sites within one year (1981), Table 2-10 presents the correlations between years for each site. The correlations within one year are much higher, with an r^2 averaging 0.75 for the upwind sites (Sites 1 and 2) during 1980 and 1981, than between years, with an r^2 averaging 0.18 for the upwind sites. This result is similar for all the data sets: The correlations are much higher between sites for any given year than at one site between years. It is to be expected that the correlation between years would be somewhat lower, since specific meteorological or site activity variables are different between years (e.g., precipitation events, occurrence of high winds, etc.) However, the same general trend of hot, dusty conditions in the summer and snowcover in the winter would intuitively lead to the conclusion that the correlations might be higher than presented in Table 2-10. Apparently, the variability of specific events between years is rather high.

Table 2-10. Annual Correlation Coefficients (r), Coefficients of Determination (r^2) and Sample Number (N) Between Years for the 24-Hr Total Suspended Particulate Concentration at Sites 1, 2, and 3, Tract C-a

	Site 1			Site 2			Site 3		
	r	r^2	N	r	r^2	N	r	r^2	N
1979 vs. 1980	0.17	0.03	120	0.43	0.19	109	0.50	0.25	108
1980 vs. 1981	0.44	0.19	117	0.40	0.16	112	0.40	0.16	107
1979 vs. 1981	0.27	0.07	119	0.35	0.13	113	0.16	0.03	107

b. Regression Analyses - The objective of these analyses is to investigate the predictive ability of a number of meteorological and site activity variables on the concentration of particulates at each of the three monitoring sites. In addition, the relative importance of these variables in explaining the TSP concentrations can be examined. For the purposes of this analysis, a set of variables has been used to establish the meteorological conditions and site activity on each sampling day. These variables were defined as:

PRECIP - precipitation on the sampling day (hundredths of an inch)

DSPREP - number of days since significant precipitation occurred (defined as 0.10 inch)

TEMP - average daily temperature (C)

WS - average daily wind speed (mph)

MAXWS - maximum hourly wind speed (mph)

WSHR12 - number of hours that average wind speed exceeded 12 mph

MNPWR - number of workers on tract

All of the meteorological variables used in the regression analysis were site specific. That is, they were collected at the same site and the same time as the TSP concentrations. The regressions were run for the total year, the summer season, and the winter season, similar to the approach used in the correlation analysis.

1. Multiple Regression - Table 2-11 gives the coefficient of determination (r^2) resulting from the multiple regression analysis. The results show that 63 percent of the variation on a yearly basis of the particulate concentrations at Site 1 can be explained by the combination of meteorological and site activity variables. Similarly, 56 percent of the variation at Site 2 and 60 percent of the variation at Site 3 can be explained by the meteorological and site activity variables.

Table 2-11. The Coefficient of Determination (r^2) and Number of Samples (in Parentheses) Resulting from the Multiple Regression of the Meteorological and Site Activity Variables on the Total Suspended Particulate Concentrations at each Site on Tract C-a During 1981

	r^2		
	Site 1	Site 2	Site 3
Total Year	0.63 (113)	0.56 (105)	0.60 (107)
Summer	0.44 (62)	0.47 (54)	0.48 (56)
Winter	0.55 (51)	0.34 (51)	0.55 (51)

At all three sites, the regressions for the individual seasons were lower than the regressions of the total yearly data set, with r^2 seasonal values averaging 0.5 at Sites 1 and 3 and 0.4 at Site 2. This may be partly due to the larger sample size for the yearly data set (which helps to reduce the impact of any inconsistent data points), and partly due to improved correlation by parameters that have an annual cycle similar to that of TSP concentrations, such as temperature.

The results of the regression analysis applied to the annual data set have been remarkably consistent over the past three years. This is especially true since some of the site activity and meteorological parameters used in the regression have been changed in an attempt to find a better fit. Regardless of the parameters chosen, the results indicate that approximately one-third of the variation in the TSP concentration at each site still remains unexplained.

2. Stepwise Multiple Regression - A further use of regression analysis is a technique known as stepwise multiple regression, in which a regression algorithm selects the meteorological and site activity variables by their importance as predictors of the dependent variable (particulate concentration). The end result is a ranking by importance of the seven independent variables (as given earlier), regardless of their classification as a meteorological or site activity variable. Tables 2-12 through 2-14 present the results of the respective stepwise regressions for Sites 1, 2, and 3. The regressions were run against three data sets from the current year: the summer season, the winter season, and the entire year. The same predictors used in the multiple regression analysis were used in this analysis. For each step in each of the regressions, the tables list the predictor entered, the coefficient of determination (r^2) for the regression containing the predictors entered thus far, the increase in r^2 from the preceeding step, and the percent increase in r^2 with the added predictor. Predictors added to each regression are included in the table up to the step where the next predictor's significance probability exceeds $\alpha = 0.05$.

A number of conclusions can be reached from this analysis (Tables 2-12 through 2-14):

- For all three sites, the predictors meeting the significance criterion ($\alpha = 0.05$) are most successful in explaining the variation in TSP concentrations when using the data set for the entire year. As discussed above, this is probably a result of the strong annual cycle that TSP concentrations exhibit, in contrast to a widely variable and perhaps partly random variation with each season. The predictors were least successful in explaining the variation at Site 2 during

Table 2-12. Results of Stepwise Regressions of Total Suspended Particulate Concentrations for Sites 1, 2, and 3 During 1981

Site 1 Data (113 cases)				
Step	1	2	3	4
Predictor	TEMP	WSHR12	PREC	MNPWR
r^2	.529	.585	.609	.622
Increase in r^2	.529	.056	.024	.013
(α) associated with adding variable to regression	.0001	.0002	.012	.0488
Site 2 Data (105 cases)				
Step	1	2		
Predictor	TEMP	WSHR12		
r^2	.465	.530		
Increase in r^2	.465	.065		
(α) associated with adding variable to regression	.0001	.0003		
Site 3 Data (107 cases)				
Step	1	2	3	4
Predictor	TEMP	WS	PREC	MNPWR
r^2	.400	.521	.565	.588
Increase in r^2	.400	.121	.044	.023
(α) associated with adding variable to regression	.001	.0001	.0018	.019

Table 2-13. Results of Stepwise Regressions of Particulate Concentrations for Sites 1, 2, and 3 During the 1981 Summer Season, Tract C-a

Site 1 Data (62 cases)			
Step	1		
Predictor	TEMP		
r^2	.384		
Increase in r^2	.384		
(α) associated with adding variable to regression	.001		
Site 2 Data (54 cases)			
Step	1	2	
Predictor	TEMP	DSPREC	
r^2	.352	.418	
Increase in r^2	.352	.066	
(α) associated with adding variable to regression	.0001	.0196	
Site 3 Data (56 cases)			
Step	1	2	3
Predictor	TEMP	WS	WSHR12
r^2	.280	.366	.424
Increase in r^2	.280	.086	.058
(α) associated with adding variable to regression	.0001	.010	.025

Table 2-14. Results of Stepwise Regressions of Particulate Concentrations for Sites 1, 2, and 3 During the 1981 Winter Season, Tract C-a

Site 1 Data (51 cases)				
Step	1	2	3	4
Predictor	TEMP	WSHR12	PREC	MNPWR
r^2	.172	.441	.497	.542
Increase in r^2	.172	.269	.056	.045
(α) associated with adding variable to regression	.0025	.0001	.026	.040

Site 2 Data (51 cases)		
Step	1	2
Predictor	WSHR12	TEMP
r^2	.158	.247
Increase in r^2	.158	.089
(α) associated with adding variable to regression	.0038	.0215

Site 3 Data (51 cases)				
Step	1	2	3	4
Predictor	WS	TEMP	MNPWR	PREC
r^2	.292	.407	.489	.541
Increase in r^2	.292	.115	.082	.052
(α) associated with adding variable to regression	.0001	.0037	.0086	.026

the winter. This may be at least partly due to the offsite activity not accounted for in the dependent variables used in the regression.

- The predictor most successful in explaining the variation in the yearly data set at each site is temperature. This one predictor had an r^2 value of at least 0.40 at each site. Of all the predictors used, it alone has an annual cycle similar to the TSP concentrations. The next most successful predictor at each site were one of the measures of the wind speed, followed by precipitation (except at Site 2, when precipitation did not meet the significance test). In no case did the site activity variable MNPWR contribute more than 0.02 to the r^2 value.

- During the summer season, the most important predictor at each site was temperature, similar to the results found for the yearly data set. The only other predictors of importance were days since significant precipitation (Site 2), and two measures of wind speed (Site 3).

- During the winter season, wind speed replaced temperature as the most important predictor at Sites 2 and 3. However, the efficiency of any individual predictor was down markedly from the other time periods.

One very important consideration related to this last point, which should be kept in mind when evaluating these results, is the relative importance of the particulate concentrations during the summer and winter seasons. That is, the particulate concentrations at each site during the winter season (with a semi-permanent snow cover) are generally quite low and tend to have minimum variations. On the other hand, the summer season is characterized by large variations in the particulate concentrations with occasional periods of high concentrations. Thus, the variation in the particulate concentrations during the winter is more difficult to predict and is also of less concern, because it is associated with very low particulate concentrations.

c. Conclusions - A number of statistical analyses were performed on the TSP data. A correlation analysis showed that Sites 1 and 2 (the upwind sites)

were highly correlated, while the correlations between these sites and Site 3 (the downwind site) were slightly less. Correlations between years at any site were found to be much lower than correlations between sites for 1981.

A multiple regression analysis was run using a combination of seven meteorological and site activity variables. The variables chosen explained almost two-thirds of the variation in annual TSP concentrations at each of the sites, a result very similar to that found during the two previous years.

The stepwise multiple regression analysis showed that the meteorological parameters were more important than site activity parameters in explaining the variation in TSP concentrations. The daily mean temperature alone explains at least 40 percent of the annual variations. Temperature is the only variable used that has a distinctly annual cycle similar to TSP concentrations, but in fact there may be more important ones (such as soil moisture). However, it serves as an easily measured indicator variable.

Measures of site activity seemed to be most successful as predictors at Site 3, In no case did the site activity variable rank higher than third in importance in explaining the TSP variability.

The conclusion after four years of attempts to determine the most important factors affecting TSP concentrations at Tract C-a is that apparently no more than two-thirds of the source of the variability can be determined using variables currently being monitored. There is apparently either a strong random component that accounts for the last one-third of the variability (such as noise in the measurement technique), or some of the parameters which are affecting TSP concentrations are not being included in the regression analysis. The situation may easily be the result of a combination of these two factors.

2.2 METEOROLOGY

Meteorological parameters are monitored to provide information on the general climate of Tract C-a and vicinity. They will also provide a basis for estimating the potential impact of emissions that may result from tract development and operation. Three meteorological sites have been in operation since the first quarter of the MDP. Meteorological data are taken at the 10-m level at each site, and also at the 60-m level at Site 1, the main sampling site. The parameters measured at each site are given in Table 2-1. Site 1 is at an elevation of 7,335 feet above mean sea level (MSL) just west of the tract boundary. Site 2 is at an elevation of 7,360 feet MSL to the southwest of the tract. Site 3 is located just east of the tract boundary in a broad gulch, at an elevation of 6,580 feet MSL. This section of the report deals primarily with the meteorological data collected from the three sites during the MDP period January-December 1981 (hereafter referred to as the current year). Meteorological data for Site 1 are presented in Appendix 2-2.1, and data for Sites 2 and 3 are presented in Appendix 2-2.2. Precipitation data and snow depth measurements are presented in Appendices 2-2.3 and 2-2.4, respectively. Barometric pressure data are presented in Appendix 2-2.5. The data for the baseline period and the first year of the MDP period were extracted from earlier reports (RBOSP 1977, RBOSC MDP Monitoring Report 3, RBOSC MDP Monitoring Report 5, and RBOSC MDP Monitoring Report 7) for comparison purposes.

A. Temperature and Stability

1. Objectives

Ambient air temperature, a primary climatic parameter, provides basic information on monthly and year-to-year variability of climatic conditions at the C-a tract. The measured vertical temperature differential within the lowest boundary layers is a measure of the stability of the atmosphere. Atmospheric stability strongly influences the dispersion of emissions into the atmosphere, and is therefore an important input into air quality models.

2. Methods

The methods followed for collection of temperature data were described in MDP Monitoring Report 3 (RBOSC 1979).

3. Results and Discussions

Table 2-15 presents a summary of monthly, seasonal, and annual temperature statistics for the current year at each of the three monitoring sites on the tract (10-m level). The temperature statistics presented for each site include means, average daily maxima, average daily minima, absolute maxima, and absolute minima.

The monthly mean temperatures for the three sites are very similar, except that Site 3 was somewhat lower than the other sites most of the time. The mean annual temperatures were 8.0 C at Site 1, 8.2 C at Site 2, and 6.3 C at Site 3.

Absolute maximum temperatures and absolute minimum temperatures at Site 1 and Site 2 were very similar, but there were generally higher maximum and lower minimum temperatures at Site 3. The extreme temperatures recorded at the tract during the current year were 31.2 C (at Sites 2 and 3) and -22.6 C at Site 3. Similarly, the average daily maximum and minimum temperatures at Site 3 were somewhat more extreme than those at Site 1 and Site 2.

The greater temperature range at Site 3 may be explained by examining the differences in site topography. Evening and late night conditions in the area are typically characterized by clear skies and light winds, resulting in strong radiational cooling at the higher elevations and subsequent drainage of the cold, dense air to lower elevations by way of the extensive gulch network. Site 3, situated in a valley, receives this cold air drainage flow from the higher elevations to the West. Sites 1 and 2 are on locally high terrain so that the cold air drains away. Due to this local circulation, Site 3 exhibits the coldest nighttime temperatures of the three sites. During the day, however, Site 3 reaches warmer maximum temperatures than Site 1 or Site 2 because of its lower elevation and the strong surface heating in the gulch.

Table 2-15 Monthly, Seasonal, and Annual Summary of Temperatures (°C) (Mean, Average Daily Maximum, Average Daily Minimum, Absolute Maximum, Absolute Minimum) January-December 1981, 10-m Level of Site 1, Site 2, and Site 3, RBOSC Tract C-a

	Site 1					Site 2					Site 3				
Period	Mean	Avg Daily Max	Avg Daily Min	Abs Max	Abs Min	Mean	Avg Daily Max	Avg Daily Min	Abs Max	Abs Min	Mean	Avg Daily Max	Avg Daily Min	Abs Max	Abs Min
January	0.0	3.3	-3.1	10.0	-9.2	0.0	3.8	-3.3	10.1	-9.7	-2.9	5.0	-9.1	12.6	-13.8
February	-0.6	3.6	-4.4	10.6	-19.9	0.7	4.1	-3.0	10.6	-10.3[1/]	-2.7	5.8	-10.4	12.6	-22.6
March	0.3	3.2	-2.8	11.3	-7.6	0.5	3.5	-2.8	11.3	-6.7	-0.3	5.6	-5.9	13.6	-13.1
April	8.7	12.7	4.2	19.9	-6.6	8.8	13.0	3.8	19.6	-6.4	8.5	16.4	-0.4	21.4	-5.9
May	8.7	13.0	4.1	21.3	-2.4	9.4	13.7	4.8	21.5	-1.6	8.9	15.1	2.1	23.5	-4.3
June	17.8	22.7	12.6	28.8	0.3	17.6	22.7	11.6	28.7	0.9	16.8	24.6	7.5	30.7	-3.0
July	19.9	24.7	14.9	29.7	9.4	19.2	24.2	15.3	29.4	11.2	19.3	26.6	11.1	31.0	6.2
August	18.8	23.1	14.9	29.2	10.4	19.6	24.4	14.6	31.2	10.4	17.5	25.1	9.6	31.2	7.7
September	15.4	19.8	11.2	23.7	4.1	15.6	19.7	10.8	24.9	3.1	14.1	21.9	6.8	25.8	-0.3
October	6.1	9.8	2.7	19.4	-5.1	5.7	9.5	2.0	19.7	-6.4	5.0	11.7	-1.0	21.8	-10.7
November	2.5	6.0	-0.5	12.0	-9.8	2.9	6.5	-0.5	13.2	-10.6	0.5	8.3	-5.8	15.4	-17.0
December	-1.5	1.4	-4.5	11.0	-13.4	-1.4	1.8	-4.6	11.1	-14.0	-3.7	3.2	-10.2	12.4	-22.1
Seasonal															
Winter (Dec, Jan, Feb,)	-0.7	2.8	-4.0	11.0	-19.9	-0.2	3.2	-3.6	11.1	-14.0	-3.1	4.7	-9.9	12.6	-22.6
Spring (Mar, Apr, May)	5.9	9.6	1.8	21.3	-7.6	6.2	10.1	1.9	21.5	-6.7	5.7	12.4	-1.4	23.5	-13.1
Summer (Jun, July, Aug)	18.8	23.5	14.1	29.7	0.3	18.8	23.8	13.8	31.2	0.9	17.9	25.4	9.4	31.2	-3.0
Fall (Sept, Oct, Nov)	8.0	11.9	4.5	23.7	-9.8	8.1	11.9	4.1	24.9	-10.6	6.5	14.0	0.0	25.8	-17.0
Annual	8.0	11.9	4.1	29.7	-19.9	8.2	12.2	4.1	31.2	-14.0	6.8	14.1	-0.5	31.2	-22.6

1/ Absolute minimum temperature at Site 2 not comparable to other sites due to station outage during coldest period.

The temperature record allows the calculation of the length of the frost-free period at each site. This information is helpful in determining the required hardiness and suitability of plants that will be used in revegetation of the tract. However, it should be noted that these temperatures are measured at 10 m above ground level, so that the first and last excursion below 0 C at 10 m (as used here) probably represents a "hard frost" at the ground surface.

Table 2-16 presents the frost-free period for the last four years at the three sites. The table also provides the 1980 and 1981 frost-free period for several climatological stations located in the vicinity of the tract. It should be noted that the National Weather Service stations measure the temperature at 2 meters, so the data are not strictly comparable to the data taken at the tract. However, they are included for reference.

The table shows that the frost-free period at Sites 1 and 2 has ranged from 111 to 156 days over the last three years, with the longest period being the current one. Site 3, being exposed to cold air drainage flows at night, has had a consistently shorter frost-free period than the other sites. Over the last three years, it has ranged from 75 to 120 days, with the current year being close to the average. The last frost date in the Spring at the tract is quite late, averaging around the first of June. The first frost date in the Fall varies considerably, ranging from mid-August to mid-October.

The frost-free periods at Meeker and Rangely are generally comparable to that measured on the tract, but at Grand Junction the period is significantly longer. This is due at least partially to the lower elevation (4800 ft. at Grand Junction vs. 7,000 ft. at the tract), and the somewhat protected valley in which Grand Junction is situated.

Table 2-17 provides a summary of annual absolute minimum, absolute maximum, and mean values of the air temperature recorded at the three sites during each of the six years of data collected to date, as well as the six data years combined. There appears to have been a slight warming trend over the data record, with the coldest mean temperature measured during the first year of the baseline and the warmest temperatures measured during 1981. The record has shown an average increase of 2.4 C over the three sites.

Table 2-16. Frost-free Period for Sites 1, 2, and 3 During the Last Four Years, and the 1981 Frost-free Period for Climatological Stations

Year	Frost-Free Period											
	Site 1		Site 2		Site 3		Meeker		Rangely		Grand Junction	
	Length (Days)	Dates	Length (Days)	Dates	Length (Days)	Dates	Length (Days)	Dates	Length (Days)	Dates	Length (Days)	Dates
1981	156	05/13-10/16	154	05/13-10/14	103	06/15-09/26	118	06/16-10/12	NA	NA	202	04/06-10/25
1980	144	05/25-10/16	NA	NA	120	05/26-09/23	101	06/02-09/11	123	06/02-10/03	192	04/14-10/23
1979	133	06/09-10/20	133	06/09-10/20	105	06/01-09/14						
1978	111	05/31-09/19	111	05/31-09/19	75	06/01-08/15						

Table 2-17. Summary of Annual and Combined Six-Year Onsite Climatology of Absolute Minimum, Absolute Maximum and Mean Values of Temperature (C) at Tract During the Baseline and MDP Periods, Tract C-a

Temperatures[1/]	2/75-1/76	2/76-1/77	1978	1979	1980	1981	Combined 6-Year Data Set
Site 1 (10m level)							
Absolute Minimum	-21.1	-21.7	-24.0	-24.6	-15.5	-19.9	-24.6
Absolute Maximum	30.1	29.7	30.4	28.5	28.0	29.7	30.4
Mean	6.1	7.2	7.1	6.6	7.6	8.0	7.1
Site 2 (10m level)							
Absolute Minimum	-21.4	-22.2	-24.1	-26.3	-15.8	-14.0	-26.3
Absolute Maximum	27.5	29.4	30.5	28.9	30.0	31.2	30.5
Mean	5.5	6.9	7.4	7.0	NA	8.2	7.0
Site 3 (10m level)							
Absolute Minimum	-28.2	-25.3	-26.8	-29.6	-22.8	-22.6	-29.6
Absolute Maximum	29.0	32.1	32.4	31.2	31.0	31.2	32.4
Mean	4.3	5.7	6.1	5.4	6.4	6.8	5.8

1/ Minimum and maximum annual temperatures are based on hourly values for each 1-year period.

Stability classifications (A-G), based upon temperature differences (ΔT) within a short vertical distance of the surface, are based on those in the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.23 (NRC 1972). The most turbulent and unstable conditions are characterized by A stability, and the least turbulent and most stable conditions are characterized by G stability.

Table 2-18 presents the frequency distribution of stability classes by month and season for Site 1, based on data from the current year. Unstable (classes A, B, and C) conditions occurred predominantly during the summer. The occurrence of stable conditions showed less seasonal dependence.

B. Dew Point

1. Objectives

Dew point data, collected since late July 1978, is used to evaluate potential cooling system alternatives. The data are more directly useable than relative humidity data, which were collected onsite for the same purposes during the baseline period and from December 1977 to late July 1978. Relative humidity can be determined from concurrent dew point and temperature measurements.

2. Methods

The methods followed for collection of dew point data were described in MDP Monitoring Report 4 (RBOSC 1979A). A new dew point monitor was installed in December, 1981 to alleviate chronic maintenance problems with an earlier instrument.

3. Results and Discussion

Table 2-19 presents a summary of monthly, seasonal, and annual dew point statistics for the current year for the data collected at Site 1. The mean monthly dew point ranged from -11.3 C in February to 5.2 C in August. The maximum dew point, 16.5 C, occurred in July, and the minimum, -26.1 C, occurred in February. The major change from a winter to a summer weather regime seems to occur in May when the mean monthly dew point jumps 8.9 C, from -7.6 to 1.3 C.

Table 2-18. Monthly, Seasonal, and Annual Occurrence (hours) of ΔT Stability Classes, December 1979 - November 1981, Site 1, Tract C-a

Period	Stability Index							
	A	B	C	D	E	F	G	Total
January	2	2	6	222	431	59	4	726
February	4	8	14	208	391	46	1	672
March	5	7	24	286	375	22	0	719
April	76	29	42	190	299	59	1	696
May	30	29	45	275	312	27	0	718
June	56	27	36	255	198	71	4	647
July	43	39	54	192	288	83	1	700
August	41	45	46	169	263	103	4	671
September	42	35	37	169	309	79	4	675
October	27	34	46	238	321	23	0	689
November	2	4	20	193	326	32	0	577
December	0	2	12	243	356	33	0	646
Spring	111	65	111	751	986	108	1	2133
Summer	140	111	136	616	749	257	9	2018
Fall	71	73	103	600	956	134	4	1941
Winter	6	12	32	673	1178	138	5	2044
Annual	328	261	382	2640	3869	637	19	8136

Table 2-19. Maximum, Minimum, and Mean Dew Point (C) at Site 1, January-December 1981, RBOSC Tract C-a

Month	Maximum Dew Point	Minimum Dew Point	Mean Dew Point
January	-2.6	-16.6	-9.3
February	-0.6	-26.1	-11.3
March	-1.3	-16.1	-6.5
April	5.4	-15.2	-7.6
May	8.6	-10.0	1.3
June	9.9	-12.5	-0.2
July	16.5	-7.3	5.1
August	11.4	-2.0	5.2
September	11.3	-8.8	3.7
October	NA	NA	NA
November	NA	NA	NA
December	-1.2	-23.1	-9.3
Season			
Winter	-0.6	-26.1	-10.0
Spring	8.6	-16.1	-4.3
Summer	16.5	-12.5	3.4
Fall	NA	NA	NA
Annual	16.5	-26.1	NA

This indicates that air masses with much higher water vapor content (allowing more precipitation) are present over the tract in May. Coincidentally, May typically has more precipitation than any other month.

C. Wind Speed and Wind Direction

1. Objectives

The wind speed and wind direction influence atmospheric dispersion. Measurement of the frequency of occurrence of wind speed and wind direction classes can also be used in interpreting air quality data.

2. Methods

The methods followed for collection of wind data were described in MDP Monitoring Report 3 (RBOSC 1979).

3. Results and Discussion

Seasonal and annual wind roses for each of the three sites for the current year are presented in Figures 2-15 to 2-22.

The Site 1 annual 10-m level wind rose for 1981 shows the prevalent wind direction to be from the west-southwest (WSW on wind rose), with secondary maxima from the south-southwest (SSW on wind rose) and southwest (SW on wind rose). The mean wind speeds associated with these directions were 7.8 mph, 8.3 mph, and 6.2 mph, respectively. These data compare well with the two annual wind roses for previous years at this site, which all show the prevalent wind direction to be from the west-southwest. At Site 1, the wind directions with the lowest frequency of occurrence, as well as the lowest annual average wind speeds, were in the southeast quadrant during all five years of the data record.

The Site 2 annual 10-m level wind rose for the current year shows the prevalent wind direction to be from the southwest, with secondary maxima from the west, west-southwest, and from the south-southwest. The mean wind speeds associated

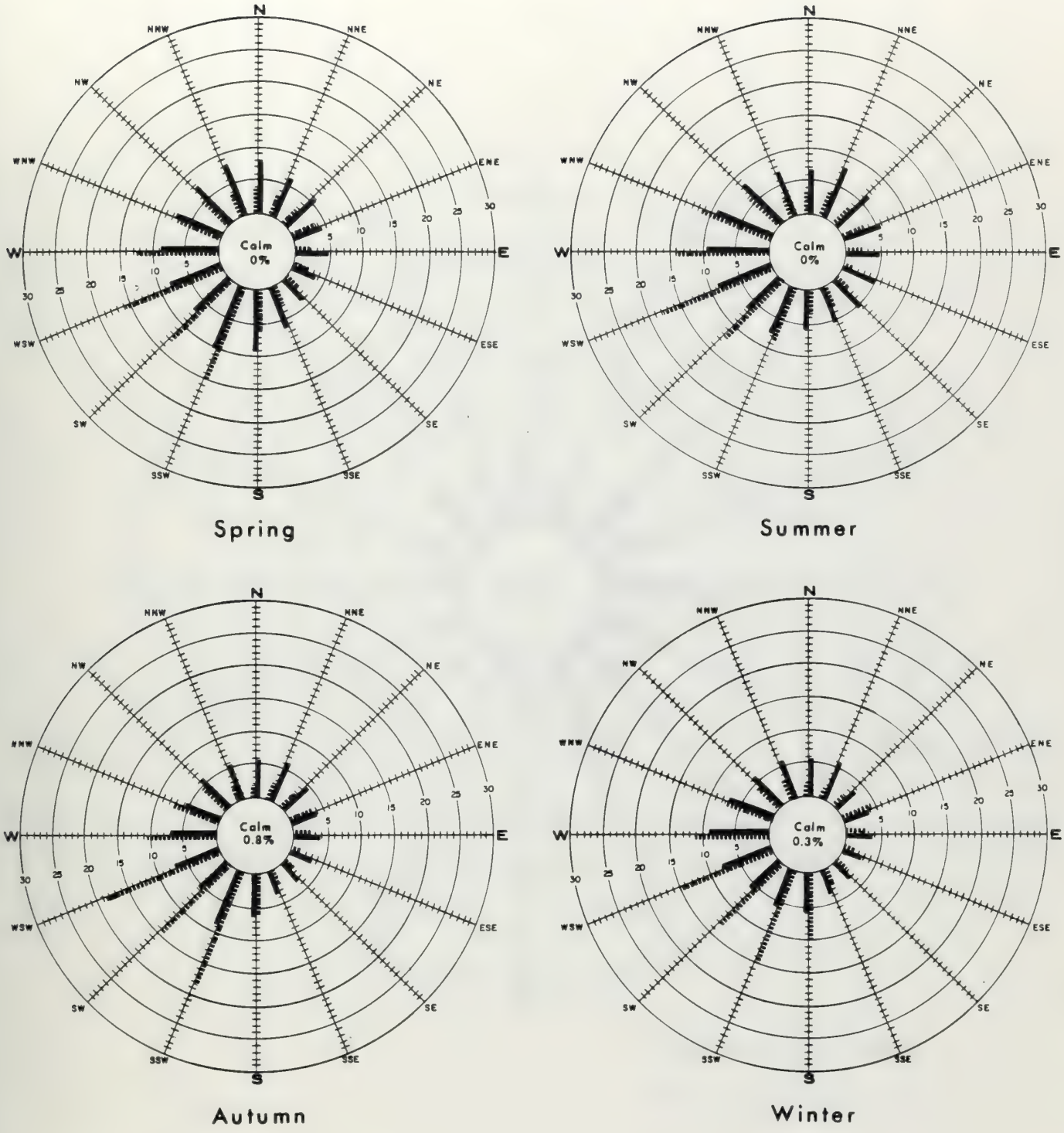


Figure 2-15. Seasonal Wind Roses, Jan.-Dec. 1981, Site 1 10-m Level, Tract C-a

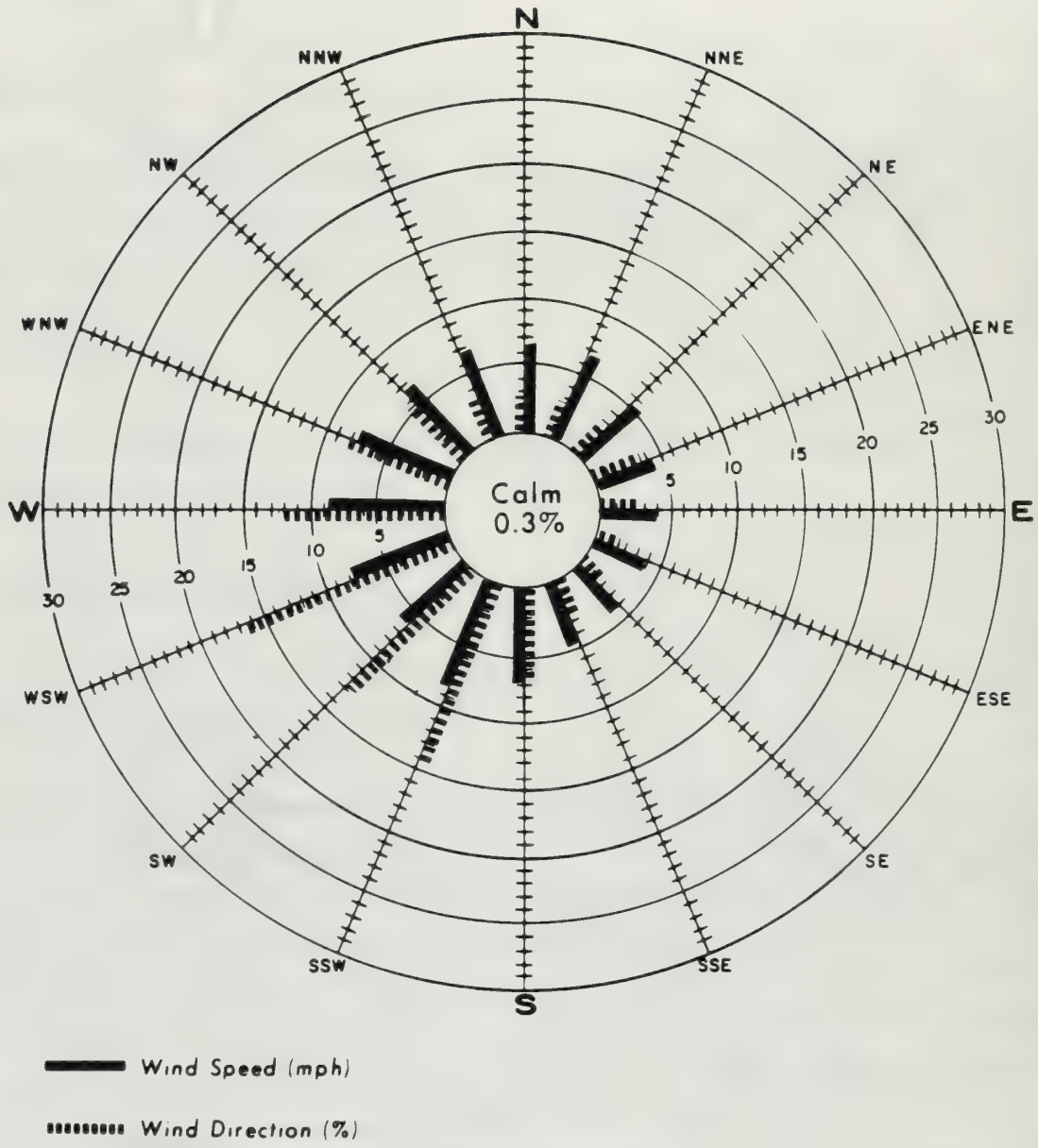


Figure 2-16. Annual Wind Rose, Jan-Dec 1981, Site 1, 10-m Level, Tract C-a

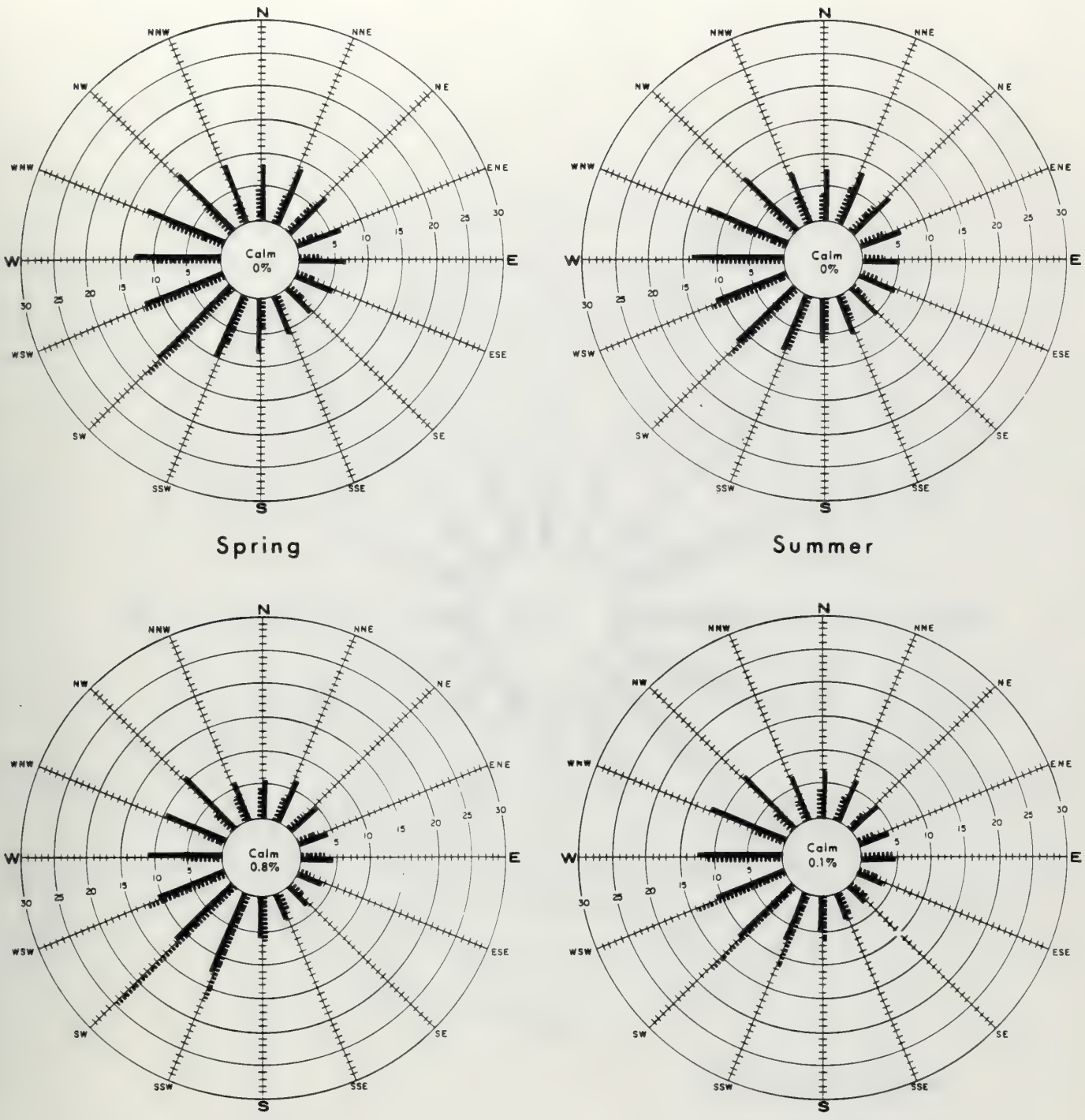


Figure 2-17. Seasonal Wind Roses, Jan.-Dec. 1981, Site 1 60-m Level, Tract C-a

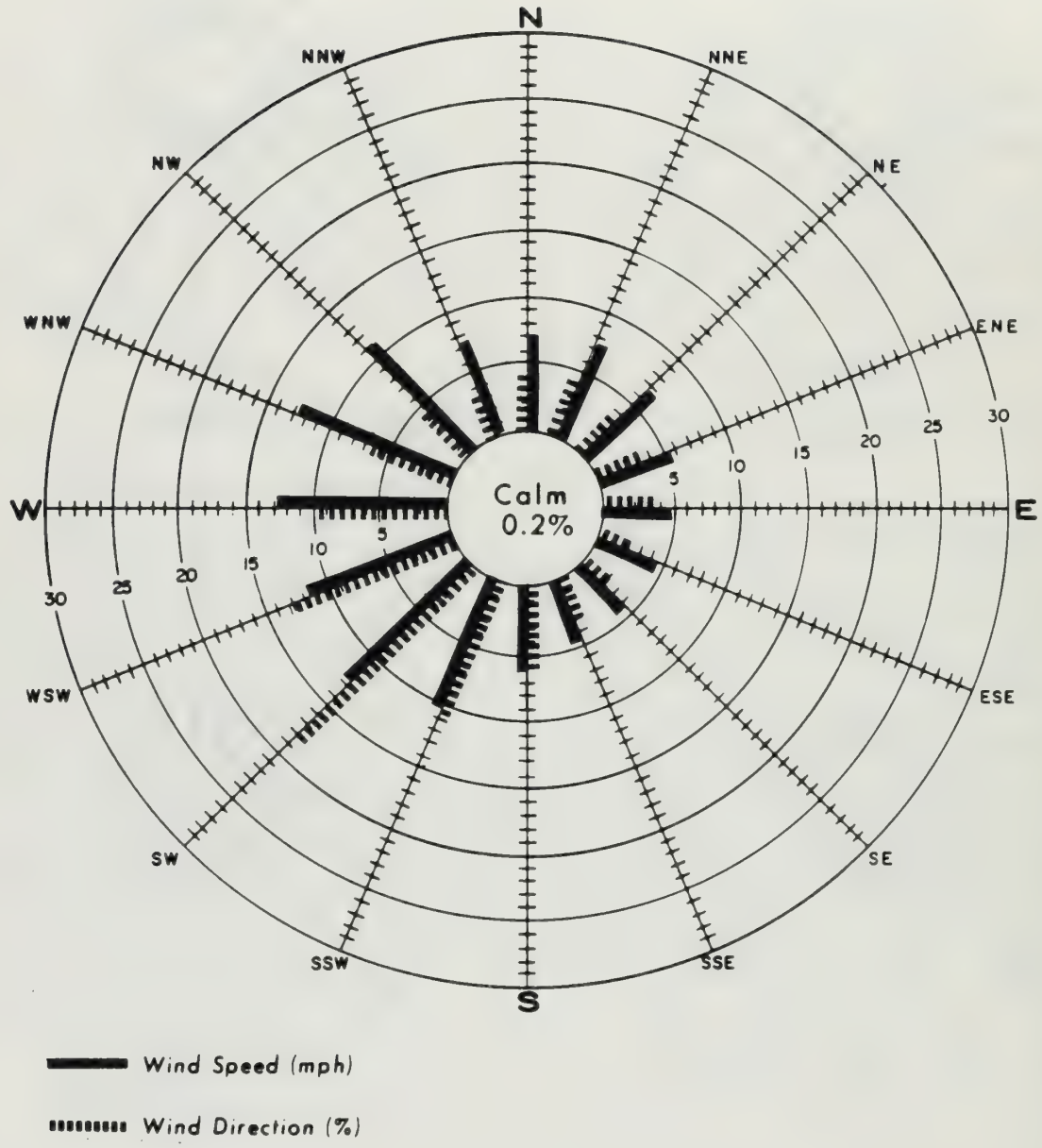


Figure 2-18. Annual Wind Rose, Jan-Dec 1981, Site 1, 60-m Level, Tract C-a

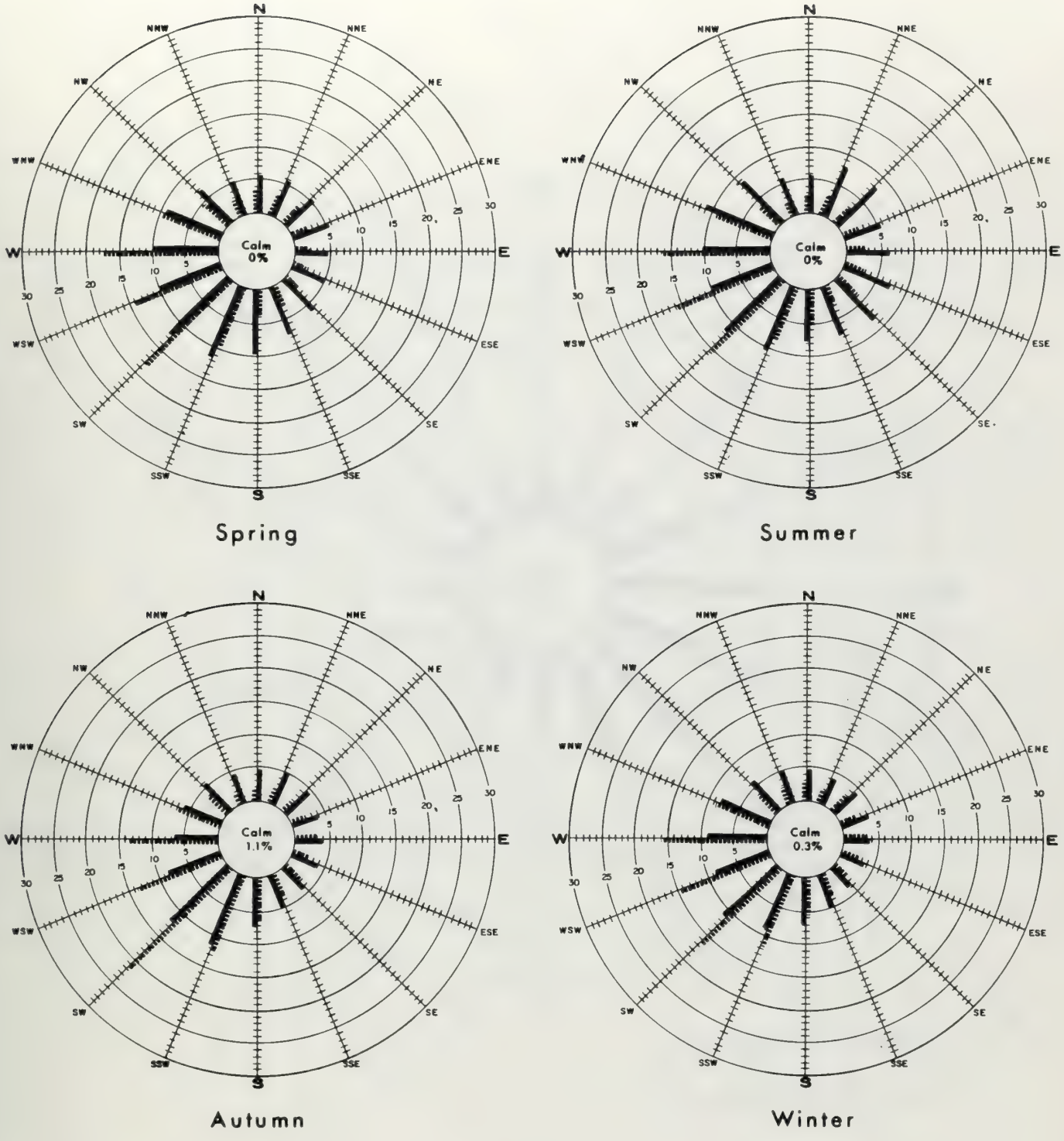


Figure 2-19. Seasonal Wind Roses, Jan.-Dec. 1981, Site 2 10-m Level, Tract C-a

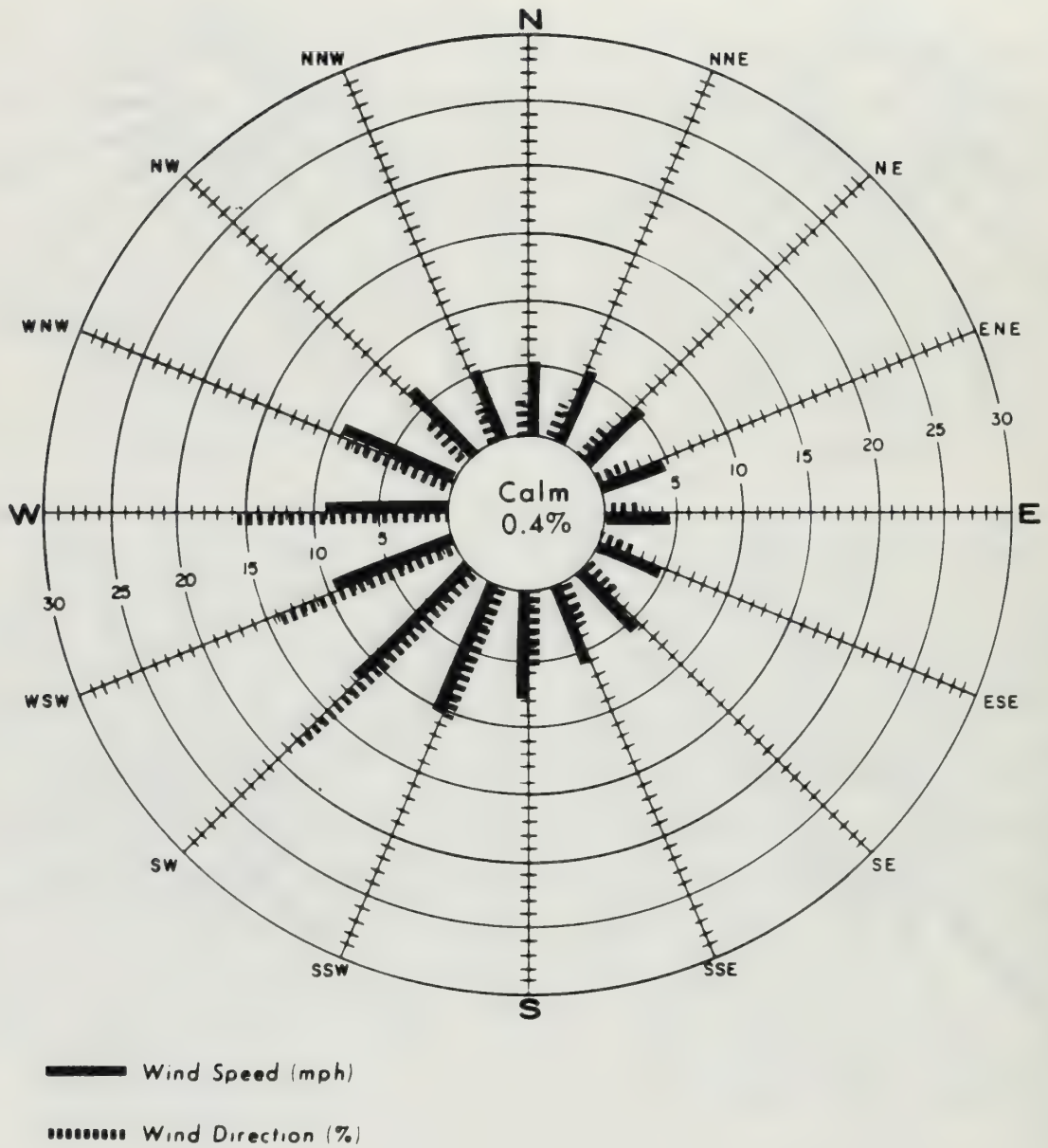
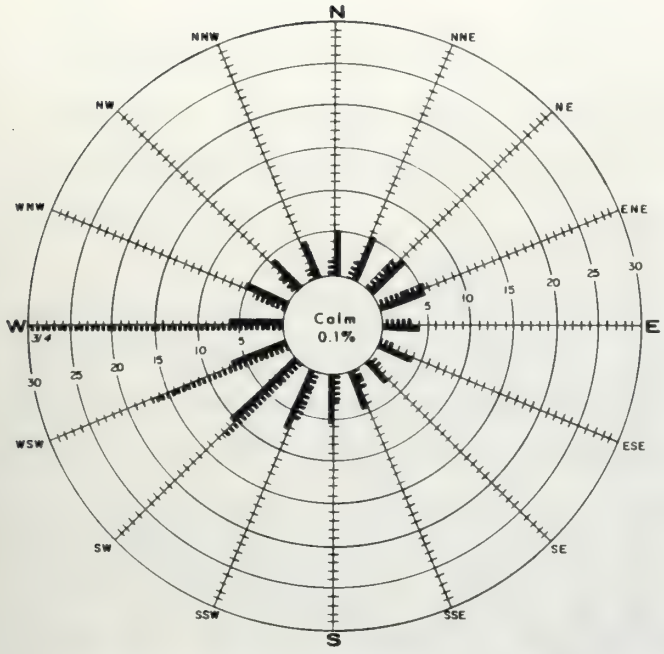
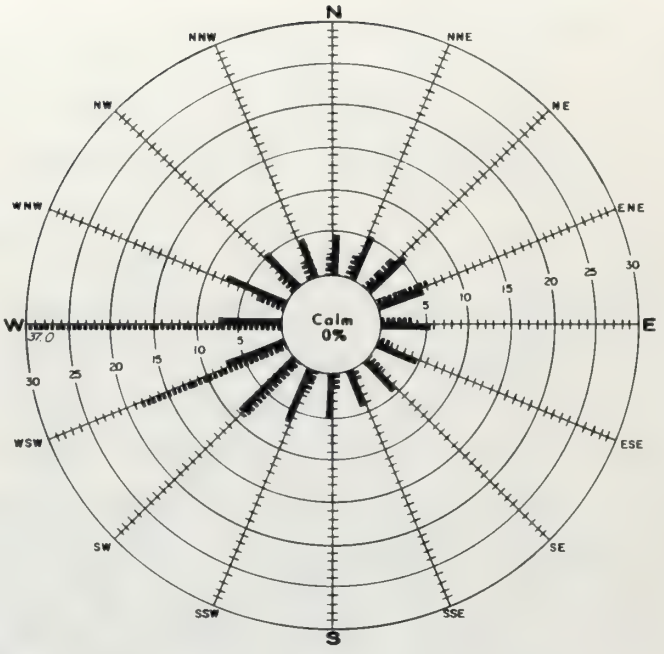


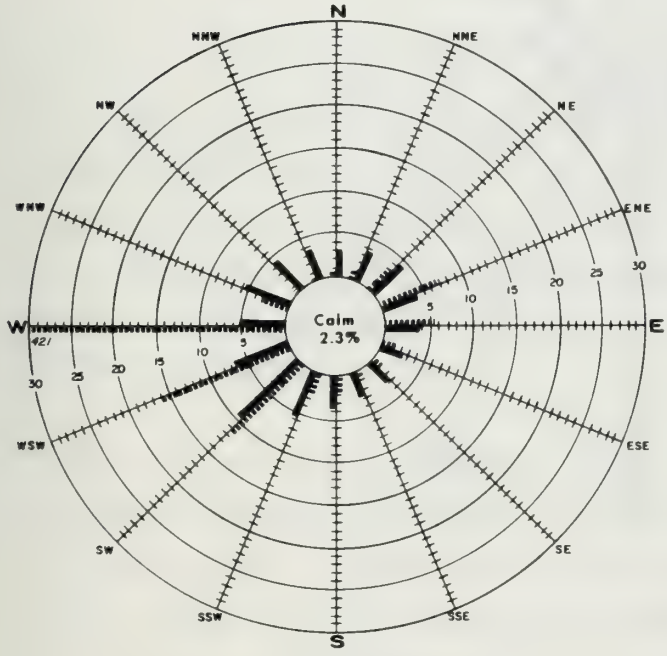
Figure 2-20. Annual Wind Rose, Jan-Dec 1981, Site 2, 10-m Level, Tract C-a



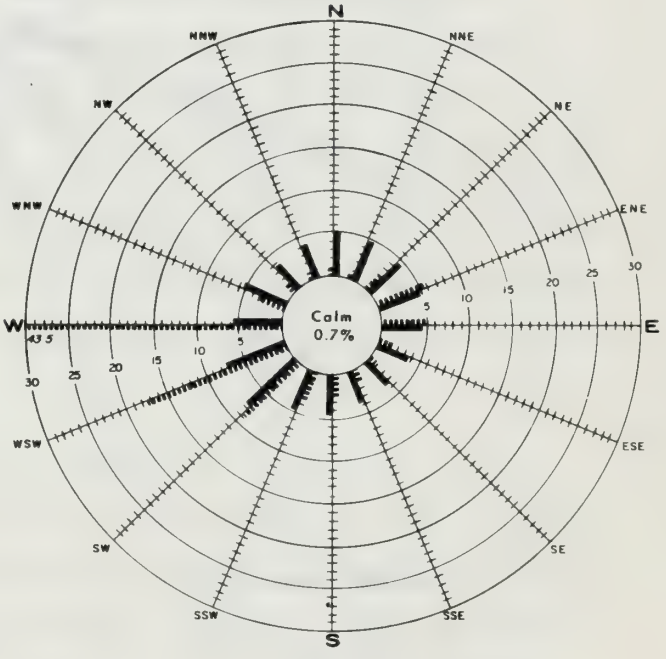
Spring



Summer



Autumn



Winter

Wind Speed (MPH)

Wind Direction (%)

Figure 2-21. Seasonal Wind Roses, Jan.-Dec. 1981, Site 3 10-m Level, Tract C-a

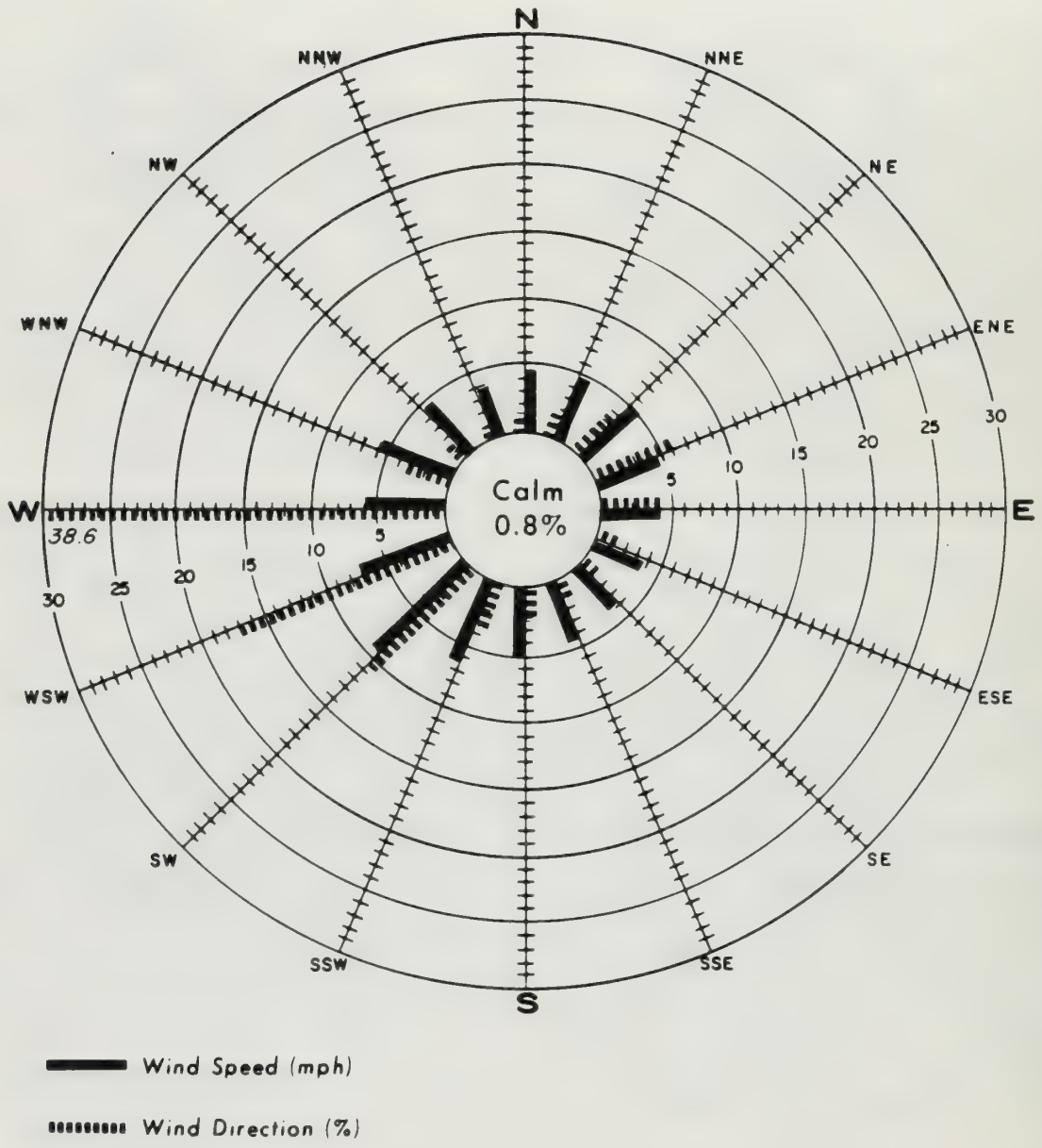


Figure 2-22. Annual Wind Rose, Jan-Dec 1981, Site 3, 10-m Level, Tract C-a

with these directions were 11.6 mph, 9.0 mph, 9.1 mph, and 10.4 mph, respectively. These data closely resemble data from previous years, which also show the prevalent wind directions to be from the west and southwest. The wind directions having the lowest frequency of occurrence and the lowest annual average wind speeds at Site 2 are in the southeast quadrant, similar to those found at Site 1.

The Site 3 annual 10-m level wind rose for the current year shows the prevalent wind direction to be from the west (38.6 percent of the time) with secondary maxima from the west-southwest and the southwest. The mean wind speeds associated with these directions were 6.0 mph, 7.0 mph, and 9.2 mph, respectively. These data are similar to the previous years of record, which also show a strong predominance of westerly winds at Site 3. This result is largely due to the influence of the east-west orientation of Corral Gulch (in which Site 3 is located) combined with the general westerly circulation and the nighttime drainage winds from the higher area to the west on Cathedral Bluffs.

Table 2-20 contains a summary of the absolute maximum and mean hourly wind speeds recorded at each of the three sites during each of the data years. The mean wind speeds for the three sites during the current year are 7.0 mph at the Site 1 10-m level, 9.7 mph at the Site 1 60-m level, 8.5 mph at Site 2, and 6.1 mph at Site 3. As shown in Table 2-20, there has been little variation in the mean wind speed during the period of record. The decrease in mean wind speeds from Site 2 (highest) to Site 3 (lowest) reflects the relative degree of sheltering by the local terrain.

Tables 2-21 to 2-24 present the annual frequency of wind direction occurrences by hour for each of the three sites (including the 60-m level at Site 1) during the current year. These tables show the same data as given in the annual wind roses, but also illustrate the variation throughout the day. Each site shows the dominance of westerly winds. The winds at Site 3 show the most extreme case, where winds from the 22.5° west sector occurred almost 70 percent of the time in the early morning hours. If the west-southwest sector is included, winds occur in these two sectors 85 percent of the time in the early morning hours. These winds are associated with downvalley drainage flows, as discussed earlier.

Table 2-20. Summary of Annual Maximum and Mean Wind Speeds (mph) at Tract C-a During the Baseline and MDP Periods

Wind Speeds (mph)[1/]	1975-76	1976-77	1978	1979	1980	1981	Combined 6-Year Data Set
Site 1 (10m level)							
Maximum	30.8	32.3	27.2	28.7	31.6	26.1	32.3
Mean	7.7	7.2	7.3	7.3	7.3	7.0	7.3
Site 1 (60m level)							
Maximum	43.0	56.6	41.5	38.0	40.8	33.8	56.6
Mean	10.6	10.0	10.2	9.5	10.1	9.7	10.0
Site 2 (10m level)							
Maximum	36.7	39.2	36.1	35.1	37.8	32.4	39.2
Mean	9.1	8.4	8.9	8.3	8.8	8.5	8.7
Site 3 (10m level)							
Maximum	29.9	26.4	22.2	24.5	26.1	22.1	29.9
Mean	6.6	6.9	6.6	6.2	6.6	6.1	6.5

[1/] Values based on hourly averages.

Table 2-21. Wind Direction Frequency (%) by Hour of Day, January-December 1981, 10-m level at Site 1, Tract C-a

Hr of Day	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
1	2.4	0.9	1.2	0.9	0.0	0.9	1.2	2.7	4.8	12.1	17.3	24.2	12.4	8.5	7.6	2.4	0.3
2	0.9	1.8	1.2	0.6	0.3	0.9	0.9	3.0	7.3	10.6	17.8	20.5	12.4	10.0	6.0	5.4	0.3
3	3.0	2.7	0.3	0.3	0.0	0.6	0.6	1.8	7.9	11.9	13.4	22.2	14.6	11.6	6.7	1.2	1.2
4	3.0	1.5	0.6	1.8	0.3	0.9	2.4	2.1	4.8	13.3	13.3	22.0	16.9	8.1	5.4	3.6	0.0
5	1.5	1.8	0.9	0.9	0.9	1.5	1.2	0.9	5.5	13.0	17.0	20.9	14.5	10.0	4.8	3.6	0.9
6	3.6	2.4	1.5	1.2	0.9	0.6	0.9	2.1	6.7	13.1	13.4	21.9	13.1	10.3	5.2	2.1	0.9
7	2.1	4.3	4.0	4.3	3.1	2.1	2.8	5.2	9.8	11.6	13.5	14.4	9.2	6.7	4.0	2.1	0.9
8	1.2	2.9	8.0	8.3	4.1	3.2	5.0	3.8	8.3	13.6	10.6	13.3	7.7	3.5	3.5	2.1	0.9
9	2.6	2.1	5.9	10.3	7.3	5.3	4.7	6.2	9.7	15.2	6.2	11.4	8.5	2.3	1.5	0.9	0.0
10	2.9	2.0	5.0	12.9	7.0	4.7	2.9	4.4	7.9	13.5	5.8	13.5	9.9	3.5	2.6	1.5	0.0
11	2.9	4.1	4.1	11.0	6.4	2.3	2.6	2.0	7.6	15.4	7.6	13.1	12.2	4.9	2.9	0.6	0.3
12	3.5	2.9	3.8	8.7	5.8	0.9	0.9	1.4	7.2	15.1	11.3	13.9	13.0	5.2	3.8	2.6	0.0
13	4.1	3.2	6.4	5.6	2.9	0.3	1.2	1.5	7.0	18.4	8.8	12.9	11.7	6.1	5.8	4.1	0.0
14	4.1	4.4	2.9	5.5	2.3	0.3	1.5	1.2	6.7	18.3	11.6	9.9	11.9	9.3	5.5	4.7	0.0
15	5.2	2.9	2.6	3.5	4.1	0.9	0.6	1.5	6.7	20.7	8.7	8.7	14.0	8.2	7.3	4.4	0.0
16	3.5	4.7	4.1	2.6	2.0	2.3	1.2	3.8	5.8	18.0	10.8	9.3	12.2	9.3	6.1	4.4	0.0
17	4.1	3.5	2.0	3.2	2.9	2.0	2.9	2.3	7.0	18.9	9.9	9.0	9.6	9.6	6.1	6.7	0.3
18	2.6	5.8	2.3	2.0	1.2	1.2	1.2	3.2	5.0	18.4	13.5	12.9	11.7	7.9	7.6	3.5	0.0
19	3.0	2.4	1.2	0.9	1.2	1.2	1.8	2.1	5.0	15.1	18.3	18.0	10.1	9.2	6.5	4.1	0.0
20	2.4	2.4	0.6	0.9	0.9	0.6	0.9	2.4	5.1	11.9	17.3	20.8	13.4	11.6	5.7	3.3	0.0
21	1.5	2.7	1.2	0.6	0.0	1.8	0.6	3.3	4.8	11.7	17.4	23.1	11.4	10.5	6.3	2.7	0.6
22	1.2	3.0	0.6	0.9	0.9	0.9	2.1	2.4	3.0	12.3	14.7	22.5	13.2	12.9	6.6	3.0	0.0
23	2.1	0.9	1.5	0.6	0.6	0.3	2.1	1.8	6.3	9.3	17.7	22.8	13.5	10.8	5.4	3.9	0.3
24	2.1	1.5	2.1	0.0	0.3	0.9	1.8	2.4	4.5	10.0	17.9	24.2	14.2	10.3	4.2	3.3	0.0
All	2.7	2.8	2.7	3.7	2.3	1.5	1.8	2.6	6.4	14.3	13.0	16.8	12.1	8.3	5.3	3.2	0.3

Table 2-22. Wind Direction Frequency (%) by Hour of Day, January-December 1981, 60-m Level at Site 1, Tract C-a

Hr of Day	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
1	5.0	5.3	5.8	1.5	1.2	0.6	2.6	2.9	7.3	12.6	17.0	13.5	10.2	5.6	4.7	3.8	0.6
2	6.7	7.3	4.1	2.6	1.8	0.6	1.2	3.5	9.1	10.6	18.5	12.6	9.1	5.9	1.8	4.4	0.3
3	5.9	7.1	5.0	2.1	1.2	0.6	1.8	5.0	5.3	9.1	16.5	16.5	9.4	7.1	2.9	3.8	0.6
4	5.0	6.2	4.4	3.2	1.8	1.5	2.4	2.7	4.7	12.4	18.0	13.9	10.6	7.1	3.2	2.9	0.0
5	6.8	4.1	3.8	1.8	0.9	1.2	2.4	3.5	7.7	11.8	16.2	15.9	10.9	5.0	3.5	3.5	0.9
6	4.4	5.9	2.7	1.5	1.5	1.2	2.4	2.9	11.2	11.2	17.7	13.9	9.7	5.0	3.5	4.7	0.6
7	3.3	4.7	5.3	3.0	2.4	2.7	3.3	4.5	11.6	11.6	17.8	11.3	7.7	5.0	3.6	2.4	0.0
8	1.8	2.4	5.3	5.9	5.3	3.8	5.3	7.1	7.1	12.1	15.3	13.5	5.9	5.0	2.1	1.8	0.6
9	1.8	2.6	2.9	5.0	9.1	5.3	5.3	3.8	9.1	11.7	15.0	13.2	6.5	4.1	2.6	2.1	0.0
10	2.1	2.1	2.6	6.5	7.9	6.2	5.6	4.4	5.0	8.2	17.3	12.3	11.1	4.1	2.3	1.8	0.6
11	1.5	2.9	3.2	5.8	8.7	5.0	1.7	3.5	3.8	7.9	17.8	14.3	14.0	4.7	3.5	1.5	0.3
12	3.8	2.0	2.9	4.7	7.9	2.9	1.5	1.7	2.3	11.1	18.7	14.6	13.7	5.2	4.7	2.3	0.0
13	4.1	4.1	3.2	4.4	4.1	2.6	0.3	1.2	2.0	11.7	19.9	13.2	12.0	7.0	6.4	3.8	0.0
14	2.9	3.5	4.1	3.5	4.7	1.2	1.2	1.2	0.9	9.3	24.1	12.5	10.2	9.9	6.4	4.7	0.0
15	5.0	2.6	2.6	2.9	4.7	1.2	1.7	1.2	1.7	7.3	24.5	10.5	13.7	9.0	5.5	5.8	0.0
16	2.3	4.3	3.5	2.9	2.9	2.0	2.0	1.4	2.6	9.3	20.3	13.3	10.7	9.6	7.5	5.2	0.0
17	1.9	2.6	4.1	2.9	2.6	2.9	2.6	2.3	3.2	9.3	19.4	10.1	9.0	9.0	9.6	5.5	0.0
18	3.8	4.9	4.9	2.9	1.4	1.4	2.3	2.9	3.5	8.7	22.6	10.4	9.0	9.6	6.7	4.9	0.0
19	4.4	5.8	3.2	1.7	0.9	2.3	1.5	2.9	5.5	13.4	18.6	14.0	8.1	5.8	7.6	4.4	0.0
20	4.4	6.4	3.5	1.2	2.0	1.2	1.2	3.2	6.1	13.5	19.9	10.8	7.9	8.8	6.1	3.5	0.3
21	5.6	5.6	3.8	2.0	1.2	0.3	2.0	2.3	8.5	14.6	17.5	14.6	5.0	8.5	5.3	3.2	0.0
22	4.7	4.4	4.1	2.3	1.2	2.0	2.0	3.8	6.1	14.9	16.1	14.0	9.1	5.8	4.7	4.7	0.0
23	6.2	3.5	4.1	2.9	1.8	1.8	0.9	2.9	7.9	11.8	17.9	14.1	8.2	5.3	4.1	6.2	0.3
24	6.2	4.4	4.4	0.6	1.8	1.8	3.2	2.3	6.5	12.9	17.9	13.8	10.6	5.6	4.4	3.5	0.3
All	4.3	4.4	3.9	3.1	3.3	2.2	2.3	3.0	5.8	11.1	18.5	13.2	9.7	6.6	4.7	3.8	0.2

Table 2-23. Wind Direction Frequency (%) by Hour of Day, January-December 1981, 10-m Level at Site 2, Tract C-a

Hr of Day	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
1	2.2	1.9	1.6	0.0	1.9	1.3	1.9	2.2	3.8	11.0	17.4	17.7	21.1	9.1	3.8	2.8	0.3
2	2.8	0.6	0.6	0.6	0.6	0.9	3.5	4.4	6.0	8.9	15.5	16.8	20.6	9.8	4.1	4.1	0.0
3	2.6	1.6	0.3	0.3	1.0	0.6	2.2	2.9	5.4	10.2	14.4	18.5	19.8	9.3	5.4	4.8	0.6
4	2.3	0.6	1.3	1.3	1.6	0.6	1.9	3.9	7.1	7.4	17.1	17.4	19.4	10.3	3.9	3.5	0.3
5	1.9	1.9	1.6	1.0	1.9	1.6	4.2	3.2	4.5	11.6	17.1	16.1	20.0	7.7	4.2	1.0	0.3
6	1.9	2.3	0.3	1.9	1.3	2.3	2.6	4.2	6.5	10.0	14.5	16.5	20.3	8.1	5.5	0.6	1.3
7	4.3	2.0	2.3	2.0	2.3	3.0	5.2	4.6	6.2	11.1	16.1	14.1	15.4	5.9	3.3	1.3	1.0
8	2.6	4.5	2.6	3.9	5.8	4.5	3.9	4.5	6.5	11.0	15.5	13.6	11.0	5.5	1.6	2.3	0.6
9	1.0	3.9	3.9	5.9	6.5	7.2	4.9	4.9	7.5	7.2	16.6	12.7	9.8	4.2	1.6	2.0	0.3
10	3.0	3.3	6.2	2.6	6.6	5.9	4.3	3.0	5.6	8.9	17.0	14.8	11.5	3.3	2.3	2.0	0.0
11	2.6	2.0	4.6	4.9	5.2	6.6	1.3	4.6	3.9	6.2	17.7	17.0	12.1	6.6	2.3	2.0	0.3
12	2.6	2.3	3.6	4.9	6.2	3.9	1.0	1.3	1.6	10.4	21.5	12.4	13.7	8.5	3.3	2.3	0.7
13	4.2	2.9	3.5	1.9	4.2	1.6	1.3	2.6	1.9	10.6	24.0	10.9	15.1	9.0	4.2	2.2	0.0
14	3.9	3.9	3.5	4.2	2.3	2.9	1.0	0.6	3.2	11.6	21.5	11.9	16.1	8.7	3.2	1.6	0.0
15	4.4	3.8	2.8	5.0	1.6	0.9	1.9	0.3	3.5	11.0	19.5	12.3	11.9	12.3	5.7	3.1	0.0
16	3.1	4.7	6.2	3.1	1.9	1.2	2.8	1.6	3.7	9.9	21.7	9.0	13.0	11.2	4.7	1.9	0.3
17	3.4	3.7	5.0	3.1	3.1	3.1	3.1	2.2	5.0	11.5	16.8	9.9	12.7	9.6	5.6	2.2	0.0
18	1.3	4.1	4.4	0.6	3.2	1.3	1.9	2.2	4.7	13.6	18.4	12.0	12.7	8.9	7.6	2.8	0.3
19	2.8	2.2	2.8	0.6	2.5	1.3	0.6	3.8	7.6	12.6	18.6	17.0	11.4	9.8	3.2	2.2	0.9
20	2.2	1.3	1.6	0.9	0.9	0.6	2.5	4.4	6.0	11.0	22.3	15.4	14.4	9.1	4.7	2.5	0.3
21	1.3	1.6	1.3	0.6	0.0	0.9	3.2	3.2	6.0	12.3	21.1	17.7	14.8	10.1	4.1	1.9	0.0
22	1.6	2.9	1.3	0.0	0.6	2.2	2.5	3.5	8.3	10.5	17.1	14.0	20.0	9.2	3.8	2.2	0.3
23	2.2	1.6	1.3	0.3	1.3	0.6	2.5	2.2	6.0	11.7	20.3	13.6	20.6	8.5	4.1	2.5	0.6
24	2.2	1.6	1.6	0.6	0.6	0.6	1.9	4.7	6.9	10.4	13.8	17.6	20.4	7.2	6.6	2.8	0.3
All	2.6	2.5	2.7	2.1	2.6	2.3	2.6	3.1	5.3	10.5	18.2	14.5	15.8	8.4	4.1	2.4	0.4

Table 2-24. Wind Direction Frequency (%) by Hour of Day, January-December 1981, 10-m Level at Site 3, Tract C-a

Hr of Day	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
1	0.6	0.0	2.7	1.2	0.9	0.9	1.2	0.9	1.5	1.5	2.7	17.5	64.7	0.9	0.9	0.6	1.5
2	0.0	0.0	0.0	1.8	1.5	0.3	0.0	1.5	0.6	1.8	4.7	16.3	64.7	3.6	1.2	0.6	1.5
3	0.0	0.9	0.9	1.5	0.6	0.3	0.9	0.3	0.6	1.5	4.7	19.5	65.4	1.5	0.6	0.6	0.3
4	0.6	0.9	0.6	1.5	0.6	0.6	0.0	0.9	2.1	1.2	3.3	16.0	67.7	1.8	0.9	0.3	1.2
5	0.3	0.6	0.9	2.1	1.5	0.3	0.3	0.6	0.6	2.1	3.3	21.8	61.2	1.8	1.2	0.3	1.2
6	1.5	0.3	1.8	0.6	1.8	0.0	0.6	0.6	1.5	1.2	1.8	14.4	67.7	2.1	1.8	0.6	1.8
7	3.6	2.7	2.7	6.0	1.8	1.8	1.5	3.3	2.4	2.1	5.1	13.8	40.5	5.4	2.4	3.3	1.5
8	2.1	1.8	6.0	14.0	9.9	1.2	1.8	0.9	2.7	5.4	7.5	15.8	24.8	2.4	1.8	0.3	1.8
9	1.8	1.2	8.2	16.6	10.0	3.0	3.3	3.9	5.4	6.6	9.7	16.3	9.4	0.9	1.5	1.2	0.9
10	1.5	4.2	6.6	16.3	17.5	4.2	1.8	1.8	3.6	5.1	11.5	12.7	7.6	2.4	1.5	0.6	0.9
11	1.8	2.7	8.3	16.4	10.1	2.7	1.8	1.2	3.3	3.3	18.2	14.9	7.7	4.5	0.9	2.4	0.0
12	2.1	3.5	5.3	9.7	10.0	2.9	0.6	0.6	3.2	6.2	22.4	13.8	12.9	3.5	1.8	1.5	0.0
13	1.8	1.2	6.3	9.9	6.9	1.2	1.8	0.6	3.9	4.5	23.7	17.4	12.3	3.9	3.3	0.9	0.6
14	1.5	4.4	4.7	8.8	5.9	2.4	0.9	1.8	1.5	5.9	23.5	16.5	14.1	4.1	1.5	2.6	0.0
15	2.3	2.9	5.3	8.8	5.0	2.9	0.6	0.9	2.6	5.0	23.7	17.0	12.9	5.8	2.6	1.8	0.0
16	4.1	2.3	3.5	9.6	5.2	1.2	1.7	1.2	2.0	7.5	21.4	18.0	12.5	5.2	2.9	1.7	0.0
17	3.2	2.9	3.8	8.3	3.5	1.2	2.7	2.1	4.7	7.7	19.5	17.1	14.2	5.3	2.1	1.2	0.6
18	1.2	2.1	3.8	4.1	2.1	1.5	2.4	0.6	5.0	4.7	13.3	20.7	27.2	7.4	1.8	2.1	0.0
19	3.0	1.8	2.1	2.7	1.5	1.8	0.3	0.6	2.4	4.2	8.6	20.5	43.2	3.9	0.9	1.2	1.5
20	1.2	0.9	2.1	0.6	1.2	0.3	1.5	0.9	1.2	3.0	4.8	19.3	55.1	3.6	2.4	0.9	1.2
21	0.9	0.0	1.5	1.2	0.3	1.2	0.9	0.3	1.5	1.2	4.8	18.5	62.2	1.5	2.4	0.9	0.9
22	0.9	0.6	3.3	1.5	0.9	0.9	0.3	1.2	0.3	2.4	4.2	15.5	61.6	4.5	1.2	0.9	0.0
23	1.2	0.6	0.9	2.1	1.2	0.3	0.3	0.9	0.9	2.4	4.2	18.9	58.9	3.6	0.9	1.2	1.5
24	0.3	0.6	0.9	1.2	1.8	1.2	1.2	1.2	2.7	0.6	3.9	19.3	59.0	3.9	1.2	0.6	0.3
All	1.6	1.6	3.4	6.1	4.2	1.4	1.2	1.2	2.3	3.6	10.5	17.1	38.6	3.5	1.6	1.2	0.8

Table 2-23 shows that a high frequency (70 percent) of westerly winds was also observed at Site 2 in the early morning hours. However, the winds at Site 2 are spread fairly uniformly over five 22.5° sectors (from south-southwest to west-northwest), instead of being confined primarily to one sector, as at Site 3. Corral Gulch is obviously very efficient at channelling the winds.

Another noteworthy phenomenon illustrated in Tables 2-21 to 2-24 is the diurnal variation in the wind direction. It is to be expected that the downvalley wind at Site 3 would reverse and become an upvalley wind shortly after sunrise, due to local solar heating of the terrain. The effect becomes moderately strong and results in an upvalley flow (against the general westerly circulation) approximately 35-40 percent of the time during the morning hours of 0900 and 1000. The tables indicate that this morning upvalley flow occurs at all three of the sites. At the 10-m level at Sites 1 and 2 it occurs between 15 and 25 percent of the time. These upslope easterly winds are much less common at other times of the day. In addition, this upslope flow appears to be fairly deep, since these easterly winds also occur with a 20 percent frequency at 0900 and 1000 hours at the 60-m level at Site 1.

D. Precipitation

1. Objectives

Precipitation is recorded to provide data on the moisture availability for plant growth and revegetation.

2. Methods

The methods followed for collection of these data were described in MDP Report 2 (RBOSC 1978A).

3. Results and Discussion

Precipitation data from the three types of measuring devices for the period June-December 1981 are included in Appendix 2-2.3. Snow depth measurements taken during the current year are presented in Appendix 2-2.4. There is a

substantial difference in the reported precipitation between the type of gauges installed at each site. The weighing bucket gauges generally have been recording somewhat higher precipitation amounts than the tipping bucket gauges. The wedge gauge data generally fall between the results from the other two gauge types.

Table 2-25 presents the monthly, seasonal, and annual precipitation at Sites 1, 2, and 3 for the current year. The table is compiled from data which are collected by tipping bucket gauges, weighing bucket gauges, and wedge gauges. Precipitation measured at the three sites during the current year ranged from 13.25 to 18.34 inches. Although the natural variability of precipitation is high in semi-arid regions, a substantial part of the range in values is thought to be due to different exposures and capture efficiencies of the gauges. Inspection of Table 2-25 reveals that the variability of precipitation on an annual basis among the three sites (located several miles apart) for the wedge gauges does not exceed 3 inches, whereas the range of precipitation among the gauges at Site 1 (located tens of feet apart), exceeded 5 inches.

The weighing bucket gauges are thought to produce the most representative precipitation data, due to a better exposure and the improvement in winter capture efficiency through the use of snow shields. The tipping bucket gauges have historically recorded lower amounts of precipitation than other gauges, which may be due to a less efficient capture and measurement technique (RBOSC 1980).

Table 2-26 presents the results of the precipitation measurements collected onsite over the last four years. Based on this record, the current year is the wettest year. The best estimate of annual precipitation, based on data from the weighing bucket gauges, indicates that precipitation totalled approximately 12 inches in 1978, 13 inches in 1979, 12 inches in 1980, and 17 inches in 1981. Table 2-27 shows the number of days with precipitation and the largest precipitation event for each month at Tract C-a. The largest event released approximately 1.4 inches of precipitation over 2 days in May. Precipitation (at least 0.01 inch) was measured on an average of 9 days per month.

Table 2-25. Monthly, Seasonal, and Annual Precipitation (inches) at Sites 1, 2, and 3 from available Tipping Bucket Gauge, Weighing Bucket Gauge, and Wedge Gauge Data at Tract C-a for the period December 1980 - December 1981

Month	Site 1			Site 2			Site 3	
	Tipping Bucket Gauge	Weighing Bucket Gauge	Wedge Gauge	Tipping Bucket Gauge	Weighing Bucket Gauge	Wedge Gauge	Tipping Bucket Gauge	Wedge Gauge
December	0.17	0.22	0.30	0.18	0.43	0.25	0.23	0.27
January	0.09	0.31	0.42	0.21	0.42	0.40	0.12	0.30
February	0.09	0.11	0.15	0.12	0.15	0.09	0.05	0.10
March	1.09	1.29	1.70	1.01	1.64	1.19	1.33	1.52
April	0.24	0.43	0.50	0.30	0.48	0.36	0.22	0.28
May	2.01	1.89	2.71	2.06	2.56	2.47	1.76	2.34
June	0.78	0.86	1.08	0.67	0.87	0.79	1.12	1.43
July	1.90	2.15	2.30	...	2.21	2.37	...	3.35
August	1.61	1.68	1.76	...	...	1.55	0.89	1.31
September	1.27	1.35	1.37	...	...	1.77	0.36	0.63
October	3.19	4.35	4.29	2.92	...	3.28	3.25	2.55
November	0.41	0.89	0.78	0.46	0.78	0.68	0.39	0.73
December	0.57	1.50	1.28	0.66	1.18	1.00	...	1.04
Seasonal								
Winter (Dec, Jan, Feb)	0.75	1.92	1.85	0.99	1.75	1.49	...	1.44
Spring (Mar, Apr, May)	3.34	3.61	4.91	3.37	4.68	4.02	3.31	4.14
Summer (Jun, Jul, Aug)	4.29	4.69	5.14	...	...	4.71	...	6.09
Fall (Sep, Oct, Nov)	4.87	6.59	6.44	...	...	5.73	4.00	3.91
Annual[1/]	13.25	16.81	18.34	...	...	15.95	...	15.58

1/ Annual and seasonal precipitation totals are for January-December 1981.

Table 2-26. Summary of Precipitation Measurements (inches) During the Last Four Years at Tract C-a

	1978			1979			1980			1981		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Tipping Bucket Gauge												
Winter	--	--	--	0.81	0.66	0.90	1.86	1.39	1.46	0.75	0.99	--
Spring	--	--	3.33	3.66	3.33	3.95	3.83	2.42	3.73	3.34	3.37	3.31
Summer	--	1.29[1/]	1.58	2.38	2.23	1.71	2.65	2.58	3.52	4.29	--	--
Fall	1.63	1.88	--	2.93	2.02	2.15	0.98	1.77	1.61	4.87	--	4.00
Annual	--	--	--	9.78	8.24	8.71	9.32	8.16	10.32	13.25	--	--
Weighing Bucket Gauge												
Winter	4.15	3.90	NA	2.24	2.37	NA	2.27	2.51	NA	1.92	1.75	NA
Spring	5.15	5.19		6.06	4.78		5.25	4.96		3.61	4.68	
Summer	--	1.14[1/]		2.17	2.58		2.56	2.94		4.69	--	
Fall	3.21	2.21[1/]		3.28	3.08		1.52	2.03		6.59	--	
Annual	--	12.44		13.75	12.81		11.60	12.44		16.81	--	
Wedge Gauge												
Winter	3.28	2.44	2.29	1.50	2.09	1.76	2.52	2.04	1.83	1.85	1.49	1.44
Spring	4.27	4.63	3.98	5.44	4.59	4.16	4.99	5.01	4.96	4.91	4.02	4.14
Summer	1.82	1.21	1.57	2.28	2.58	1.95	3.25	2.89	3.43	5.14	4.71	6.09
Fall 2.94	2.70	2.32	2.43	2.15	2.45	2.38	2.24	2.00	6.44	5.73	3.91	
Annual	12.31	10.98	10.16	11.65	11.41	10.32	13.14	12.18	12.22	18.34	15.95	15.58

[1/] Partial data only

Table 2-27. Number of Days with Precipitation and Largest Precipitation Event (inches) for Each Month at Sites 1, 2, and 3, Tract C-a

Month	Site 1		Site 2		Site 3	
	No. of Days With Precip.	Largest Event (Length in Days)	No. of Days With Precip.	Largest Event (Length in Days)	No. of Days With Precip.	Largest Event (Length in Days)
January	4	0.12(1)	6	0.16(1)	4	0.17(1)
February	5	0.07(2)	4	0.10(1)	4	0.05(1)
March	16	0.35(1)	13	0.78(4)	13	0.34(2)
April	7	0.35(3)	5	0.24(2)	5	0.17(3)
May	14	1.23(2)	14	1.44(2)	13	1.37(2)
June	7	0.64(3)	4	0.77(3)	6	0.88(3)
July	11	0.97(3)	9	1.07(4)	11	0.83(4)
August	11	0.72(2)	11	0.73(5)	11	0.50(5)
September	11	0.86(3)	10	1.33(2)	11	0.35(3)
October	13	1.47(6)	13	0.81(3)	12	0.94(3)
November	7	0.50(3)	6	0.45(1)	5	0.42(1)
December	10	0.52(3)	8	0.57(2)	8	0.41(2)

The wettest month during the current year was October, when approximately 25 percent of the total annual precipitation fell. May and July were the next wettest months, accounting for another 25 percent of the annual precipitation. In the past, Spring has been the wettest season whereas Fall has been one of the driest seasons. This year, fall was the wettest season, followed in decreasing order by summer, spring, and winter.

An analysis of the precipitation data has shown that, over the last three years, an average of 75 percent of the precipitation came in "major" storms (0.40 inches or greater). In 1979, there were 12 major storms and 13 inches of precipitation; in 1980, there were 11 storms and 12 inches of precipitation; in 1981, there were 15 storms and 17 inches of precipitation. There appears to be a very good correlation between the number of storm events and total annual precipitation. Thus, the difference between a wet year and a dry year at Tract C-a seems to be determined by whether the upper air circulation directs an above-average or below-average number of major storms over the area. Since these occur infrequently, it follows that a "wet" year can be the result of only a few additional storms that happen to occur in one or two months.

E. Solar Radiation

1. Objective

Solar radiation is monitored to supplement the data base for interpreting air quality data.

2. Methods

The methods followed for collection of these data were described in MDP Monitoring Report 4 (RBOSC 1979A).

3. Results and Discussion

Table 2-28 presents the maximum and mean (based on daylight hours only) monthly solar radiation at Site 1 for the current year. Mean monthly solar radiation ranged from 0.33 ly/min in December to 0.67 ly/min in June. The mean monthly solar radiation values peaked during the month of the summer solstice (June)

Table 2-28. Maximum and Mean Solar Radiation (ly/min) at Site 1, January-December 1981, RBOSC Tract C-a

Month	Maximum[1] Solar Radiation (ly/min)	Mean[1] Solar Radiation (ly/min)
January	0.79[1]	0.33
February	1.06	0.40
March	1.28	0.43
April	1.41	0.62
May	1.47	0.51
June	1.44	0.67
July	1.41	0.58
August	1.36	0.55
September	1.29	0.48
October	1.02	0.43
November	0.77	0.33
December	0.66	0.30
Season		
Winter	1.06	0.34
Spring	1.47	0.52
Summer	1.44	0.60
Fall	1.29	0.41
Annual	1.47	0.47

[1] Maximum and mean values computed from hourly average.

and decreased fairly symmetrically toward the winter solstice (December). The only exception was in the spring, when April had a higher mean solar radiation (0.62 ly/min) than did May (0.51 ly/min). May had more precipitation and was a cloudier month than April (Table 2-28 shows that April had 7 days and May had 14 days with precipitation), thus resulting in a lower mean monthly solar radiation.

2.3 CLIMATOLOGY

This section presents a description of the general climatology of the region in which Tract C-a is located.

1. Objectives

It is the intent to develop a climatology by comparing meteorological data collected from the three RBOSC sites (defined as "onsite") with both short-term and long-term climatic data available from other meteorological stations in the region. The rugged topography of western Colorado causes variations in climate within short distances, and caution must be used when applying climatic generalizations to the whole area. Ideally, the most accurate way of characterizing the climatology of Tract C-a is to develop a long-term meteorological data base from data gathered onsite. The available onsite meteorological data base of six years cannot be construed as being representative of the long-term climatic conditions in the tract area; however, the onsite data can be compared with similar short-term and long-term data in the region to identify site-specific climatic conditions due to elevation, exposure, and the orientation of mountain ranges and valleys.

2. Methods

The methods followed for collection of climatological data were described in MDP Monitoring Report 3 (RBOSC 1979).

3. Results and Discussion

Figure 2-23 presents the sources of climatological data in the northwest section of the State of Colorado, where Tract C-a is located at an average elevation of 7000 feet above MSL. The weather station closest to the tract is Little Hills, located 15 miles to the northeast at an elevation of 6140 feet. The Meeker No. 2 station is located about 30 miles to the east-northeast at an elevation of 6350 feet. The Rangely station is located about 20 miles to the west-northwest at an elevation of 5220 feet. Grand Junction, at an elevation of 4843 feet, is about 60 miles south of the site. All of these stations monitor temperature and precipitation. At Grand Junction other parameters are measured as well.

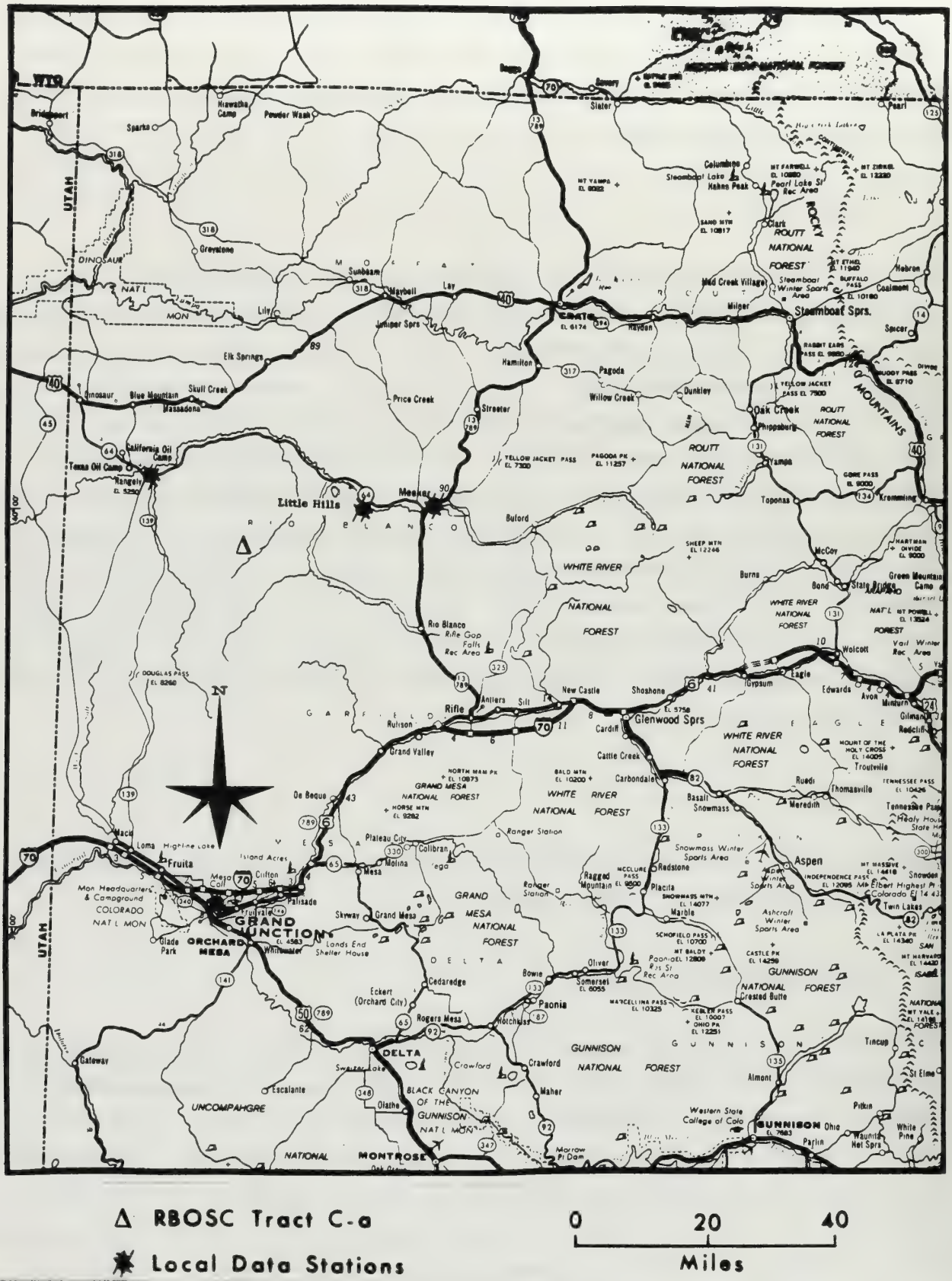


Figure 2-23. Map of Northwest Colorado Showing the Rio Blanco Region

The following is a discussion of the climatology of the area and the influences of the topography on the general meteorological and climatic conditions in the area. It has been extracted from the Baseline Report (RBOSP 1977):

> The Tract C-a area is surrounded by high mountains. As a result, many migratory low pressure systems are deflected around the region. Stationary high-pressure cells often persist for several days, their passage blocked by the Continental Divide east of Tract C-a. As a result, there is a high frequency of clear sunny days with light winds and large diurnal temperature changes. Gradient winds are generally westerly, existing throughout the year, except when interrupted by the passage of frontal systems. Precipitation measurements indicate relatively low annual accumulations such as those of semi-arid steppe regions. In addition, the data indicate a high degree of temporal and spatial variability in this area, which is to be expected given the rough terrain with its variations in elevation and exposure. The infrequent occurrences of precipitation, fog, and small light-scattering airborne dust have produced excellent visibility, in general, for the Tract C-a area.
>
> Local topography within the Tract C-a area has a much more pronounced effect on surface flows than the macroscale processes. Specific air movements produced by local conditions are often different from those expected from the major gradient flow. There is a tendency for wind velocities to be lowest at sunrise, when there is little vertical thermal mixing and the lower surface air does not couple with the more freely moving upper air. Conversely, velocities of local winds are greatest in the early afternoon hours when the air exhibits its greatest tendency to move vertically due to terrestrial heating, and couples with the faster air moving above it.
>
> In the absence of strong gradient winds, the local terrain produces special meteorological conditions. During warm afternoon hours, the laterally constricted, but vertically expanding, air tends to flow up the valley. This air motion probably develops simultaneously with anabatic (upslope) winds which result from a greater heating of the valley sides than the valley floor. At night, the reverse process occurs with the cold, dense air at higher elevations draining into the depressions. The greater radiative heat loss affecting the higher

elevations (especially if they are snow covered) cools the air immediately adjacent to the surface, and this air sinks into the valley. Downward flowing cold air set in motion by this effect forms downslope winds leading to an accumulation of cold, dense, stable air in the valley bottom.

The high Cathedral Bluffs to the west of Tract C-a and the deep gulches to the east effectively channel surface winds, and thereby decouple the upper level flows from the surface flows much of the time. Several studies have shown that airflow within the canyons of the Piceance Creek and Yellow Creek Basins is influenced by drainage winds in their respective channels, whereas winds measured atop the ridge-like portions of the basin closely follow the gradient wind regime. It can be inferred that these drainage winds occur in conjunction with stronger temperature inversions within the valley than at the ridge regions.

Meteorological data collected at the site during the current year can be compared to data for the same period from Grand Junction and to the Grand Junction long-term averages for the period 1941-1970. Table 2-29 presents the monthly departures from normal for Grand Junction mean temperature, total precipitation, mean relative humidity, and mean wind speed during the current year. The departure during the current year of the mean annual temperature at Grand Junction from the long term average was +2.5 F. The Grand Junction mean annual temperature exceeded the RBOSC Site 1 mean during the current year by 8.8 F. The annual precipitation during the current year at Grand Junction was 2.37 inches above the long-term average, but 8.03 inches below the total measured at Site 1 for the year. The Site 1 mean wind speed was 1.6 mph lower than the Grand Junction mean wind speed for the current year.

Table 2-29 indicates that Grand Junction data compares rather poorly with onsite data. The decrease in mean annual temperature of 9 F from Grand Junction to Tract C-a has been relatively constant for the last two years (RBOSC 1980). In addition, an increase in annual precipitation totals from Grand Junction to Tract C-a has occurred in each of the last three years, although the difference of 8 inches in 1981 has been the largest. Consequently, Grand Junction data should be used very cautiously in describing the climatology of the tract. This climatological difference between Site 1 and

Table 2-29. Monthly Departures from the Long-term Means for the Data Period January-December 1981 for Grand Junction and Comparison with Tract C-a Annual Values

	Month	Temperature (F) Long Term Mean	1979-1980 Mean	Departure From Mean	Precipitation (inches) Long Term Mean	1979-1980 Mean	Departure From Mean	Relative Humidity[1] (%) Long Term Mean	1979-1980 Mean	Departure From Mean	Mean Wind Speed (mph) Long Term Mean	1979-1980 Mean	Departure From Mean
Grand Junction	January	26.6	36.8	+ 10.2	0.64	0.44	- 0.20	70	57	- 13	5.6	6.7	+ 1.1
	February	33.6	37.9	+ 4.3	0.01	0.16	- 0.45	56	46	- 10	6.7	7.4	+ 0.7
	March	41.2	44.0	+ 2.8	0.75	1.35	+ 0.60	44	56	+ 12	8.4	8.4	0.0
	April	51.7	56.8	+ 5.1	0.79	0.56	- 0.23	40	39	- 1	9.7	9.5	- 0.2
	May	62.2	60.9	- 1.3	0.63	1.49	+ 0.86	34	44	+ 10	9.6	10.1	+ 0.5
	June	71.3	76.4	+ 5.1	0.55	0.17	- 0.38	31	27	- 4	9.8	9.7	- 0.1
	July	78.7	79.4	0.7	0.46	0.41	- 0.05	33	38	+ 5	9.3	10.0	+ 0.7
	August	75.4	76.8	+ 1.4	1.05	0.82	- 0.23	35	38	+ 3	9.0	9.7	+ 0.7
	September	67.2	69.2	+ 2.0	0.84	0.25	- 0.59	38	42	+ 4	9.0	8.8	- 0.2
	October	54.9	50.7	- 4.2	0.93	2.06	+ 1.13	44	62	+ 18	7.9	8.8	+ 0.9
	November	39.8	41.6	+ 1.8	0.61	0.47	- 0.14	57	63	+ 6	6.6	7.6	+ 1.0
	December	29.5	31.3	+ 1.8	0.55	0.60	+ 0.05	67	74	+ 7	5.9	6.5	+ 0.6
	Annual	52.7	55.2	+ 2.5	7.81	8.78	+ 0.97	46	49	+ 3	8.1	8.6	+ 0.5
RBOSC Site 1		NA	46.5	NA	NA	16.81	NA	NA	NA	NA	NA	7.0	NA
RBOSC departure from Grand Junction		NA	- 8.8	NA	NA	+ 8.03	NA	NA	NA	NA	NA	- 1.4	NA
RBOSC Site 1 6-yr Mean[2]		44.8			13.62[3]				NA		7.3		

[1] Based on daily averages of eight readings.

[2] The RBOSC 6-year mean data does not constitute a long term mean.

[3] Based on a 4-year data record.

Grand Junction can also be seen in the frost-free period (Table 2-16), which was 46 days longer during 1981 at Grand Junction.

This difference is not unexpected, since Grand Junction is located in a valley approximately 2500 feet lower than Site 1. In fact, an estimate can be made of the temperature that would be expected if the Grand Junction station was at the same altitude as Site 1, by using the NACA Standard Atmosphere lapse rate for 40°N latitude of 3.57 F/1000 ft (Hess 1959). Using this approximation, the Grand Junction mean annual temperature would be reduced by 8.9 F. Thus, the large discrepancy in mean annual temperatures between the site and Grand Junction can be accounted for simply by the altitude differential. However, it should be emphasized that topographic influences can also be large: whereas the standard lapse rate indicates that Site 3 should have a mean annual temperature 2.8 F higher than Site 1, the mean temperature at Site 3 in 1981 was 2.2 F lower than Site 1.

Table 2-30 presents monthly temperature data collected during the current year from Site 1, three surrounding climatological stations (Rangely, Meeker No. 2, and Little Hills), and Grand Junction. The table shows that Grand Junction temperature data are not very representative of Rio Blanco County. The mean monthly and annual temperatures at the three climatological stations in the county agree well with the onsite data, especially considering the elevation and topography differences among the sites. A major difference between Site 1 and the other stations is evident, however, in the average temperature range. This is due primarily to the relative height of the instruments above the ground surface. All climatological stations measure temperature 6 feet above the ground in a standard weather shelter, whereas the Site 1 temperature sensor is located at 10 m (33 ft.). Since temperature changes in the lower layers of the atmosphere result from heat transfer to and from the ground surface, the diurnal temperature range will decrease with height above the ground. Thus, the reduced temperature range at Site 1 relative to the surrounding stations is largely due to the increased height of the temperature sensors at Site 1.

Table 2-31 presents a comparison of precipitation data from Site 1 and from surrounding stations for the current year. Monthly precipitation amounts at all of the stations vary widely due to the complex orographic influences of the

Table 2-30. Comparison of Monthly Temperatures (F) in the Vicinity of Tract C-a for the Data Period January-December 1981

Month	Tract C-a Site 1			Little Hills			Meeker No. 2			Rangely			Grand Junction		
	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean
January	37.9	26.4	32.0	47.1	5.5	26.3	46.7	15.5	31.1	46.4	12.7	29.6	48.7	24.9	36.8
February	38.5	24.1	30.9	45.7	6.4	26.1	46.7	14.4	30.6		M		51.9	23.9	37.9
March	37.8	27.0	32.5	48.3	18.1	33.2	49.3	22.1	35.7	53.8	26.0	39.9	54.5	33.4	44.0
April	54.9	39.6	47.7	62.0	23.3	42.7	64.7	26.5	45.6	69.6	35.5	52.6	70.9	42.6	56.8
May	55.4	39.4	47.7	64.8	31.8	48.3	66.1	35.8	51.0	70.4	41.0	55.7	73.6	48.1	60.9
June	72.9	54.7	64.0	80.8	37.2	59.0	82.6	44.4	63.5		M		91.8	61.0	76.4
July	76.5	58.8	67.8	85.5	43.0	64.3	85.5	50.5	68.0	92.5	54.4	73.5	93.5	65.3	79.4
August	73.6	58.8	65.8	82.9	38.4	60.7	83.2	45.2	64.2	90.6	52.3	71.5	90.5	63.0	76.8
September	67.6	52.2	59.7	77.5	33.8	55.7	78.2	40.6	59.4	83.4	47.0	65.2	82.5	55.8	69.2
October	49.6	36.9	43.0		M		58.6	34.0	46.3	63.2	33.3	48.3	60.9	40.5	50.7
November	42.8	31.1	36.5		M		50.7	22.3	36.5	51.4	21.5	36.5	53.0	30.1	41.6
December	34.5	23.9	29.3		M		42.0	16.7	29.4	40.9	12.6	26.8	40.6	21.9	31.3
Annual			46.4						46.8						55.2

M = Missing data.

Table 2-31. Comparison of Monthly Precipitation (inches) in the Vicinity of Tract C-a for the Data Period January-December 1981

Month	Tract C-a Site 1	Little Hills	Meeker No. 2	Rangely	Grand Junction
January	0.31	0.20	0.28	0.32	0.44
February	0.11	0.76	0.35	N/A	0.16
March	1.29	2.82	2.27	2.02	1.35
April	0.43	0.23	0.39	1.52	0.56
May	1.89	3.20	3.02	1.89	1.49
June	0.86	1.11	0.72	M	0.17
July	2.15	1.44	1.27	0.71	0.41
August	1.68	1.07	1.30	1.00	0.82
September	1.35	0.44	0.47	1.21	0.25
October	4.35	4.32	4.37	4.35	2.06
November	0.89	0.54	0.93	0.41	0.47
December	1.50	1.09	1.42	0.52	0.60
Annual	16.81	17.22	16.79	M	8.78

M = Missing Data

region and the intermittent nature of precipitation (particularly during the summer), but annual totals are reasonably close. Grand Junction had the lowest monthly precipitation totals of all stations, probably because of its protection by surrounding higher terrain.

2.4 QUALITY ASSURANCE AND DATA RECOVERY

The data summaries incorporated in the appendices, with the exception of precipitation and particulate data, were prepared from data acquired by an automatic data acquisition system located on Tract C-a. The data are recorded both on magnetic tape and analog strip chart recorders. A comprehensive quality assurance program has been maintained to ensure the reliability and accuracy of the data. This program includes documentation by the site technician of all calibrations and system malfunctions, weekly zero and span calibrations of the air quality instrumentation, utilization of control charts onsite to detect problems in the weekly span calibrations, quarterly calibrations of the air quality instrumentation by both the RBOSC technical staff and an independent auditing team, semiannual calibrations of the meteorological instrumentation, and review of the analog and digital data by qualified analysts.

The air quality instruments are calibrated with reference gases traceable to National Bureau of Standards (NBS) standards. The carbon monoxide, sulfur dioxide, hydrogen sulfide, and nitrogen oxide analyzers were calibrated using known concentrations of test gases which had been certified by the vendor. The ozone analyzer is calibrated using a U.V. photometer.

Each instrument was tested at least once a week by inserting a zero pollutant concentration and at least one upscale concentration. These tests provided data on instrument drift and ensured that the instrument would respond to a detectable level of pollutant concentration in the ambient air.

The quarterly field calibrations were used to determine the accuracy of the instruments. An independent audit by an EPA contractor (Rockwell International) was used to check the internal calibration methods. Due to technical problems associated with the calibration of the ozone analyzers using the new U.V. photometer, the analyzers were adjusted too low, and a minor correction had to be applied to the data for a short period to bring the data within 10 percent of the true values. The ozone data was increased at Site 1 by 17 percent from August 20 to September 3, 1981, and increased by 16 percent at Site 3 from August 27 to September 3, 1981.

The air quality data include many values representing hours when the concentration of some pollutants fell below the reliable threshold of detection of the instrument (based on the manufacturer's specifications). When this occurred, a number equal to one-half the threshold value was substituted for the data point. This procedure is adopted from the EPA Quality Assurance Handbook, Air Pollution Measurement, Vol. 1. This applied to sulfur dioxide, hydrogen sulfide, nitrogen oxides, and carbon monoxide data acquired through much of the data period.

The meteorological system is calibrated on a semiannual basis. This includes routine replacement of all wind speed and wind direction sensors. No correction factors were required to adjust the data.

Data recoveries for all meteorological and air quality parameters collected by the onsite data acquisition system are presented in Tables 2-32 and 2-33. The data recovery of all meteorological parameters met or exceeded the 75 percent level recommended by the EPA, with the exception of the dewpoint at Site 1. A new dewpoint sensor, installed in December, should correct this problem. The data recovery of the air quality parameters at Sites 1 and 3 also exceeded the 75 percent criterion.

Table 2-32. Annual Data Recovery (%) of Air Quality Parameters Monitored at Tract C-a for the Period January-December 1981

Parameter	Data Recovery (%)
Site 1	
O_3	92
CO	92
NO	90
NO_x	90
H_2S	89
SO_2	92
Site 3	
O_3	88
CO	92
NO	89
NO_x	89
H_2S	91
SO_2	88

Table 2-33. Annual Data Recovery (%) of Meteorology Parameters Monitored at Tract C-a for the Period January-December 1981

Parameter	Data Recovery (%)
Site 1	
10 m wind speed	92
10 m wind direction	94
60 m wind speed	94
60 m wind direction	94
10 m temperature	93
60 m temperature	93
ΔT 60-10 m	93
dew point	68
solar radiation	88
Site 2	
10 m wind speed	86
10 m wind direction	86
10 m temperature	85
Site 3	
10 m wind speed	92
10 m wind direction	93
10 m temperature	93

2.5 VISIBILITY

Documentation of visibility in the Piceance Creek Basin is a cooperative study conducted by RBOSC and the Cathedral Bluffs Oil Shale Company.

1. Objectives

The objectives of this program are to document the visibility in the area of the Piceance Creek Basin and identify trends or variations in visibility which may be evident during the monitoring program. The results of this program will provide visibility data against which past and future data may be compared and with which concurrent meteorological and air quality data may be incorporated for further evaluation and consideration.

2. Methods

Two methods are being employed to measure basin-wide visibility during the spring and fall studies. A photometric method incorporates techniques identical to those utilized during the baseline study to calculate visual ranges; these techniques were described in MDP Monitoring Report 1 (RBOSC 1978). A second method uses a telephotometer to derive visual ranges. Data are normally collected every sixth day from a centrally located shelter (Figure 2-24) during the spring and the fall.

3. Results and Discussion

This analysis, similar to the earlier studies in 1975-76, 1978, 1979, and 1980, is based only on the photometric data. Comparisons between the two methods will be made after reduction of the telephotometer data has been completed.

During the 1981 monitoring period, visual range measurements were made on 9 of the 10 scheduled days during two months in the spring and on all 10 days during two months in the fall. A late snowcover on the target peaks, as well as access problems to the monitoring site, prevented the spring monitoring program from beginning before May, which extended the sampling period through June. In

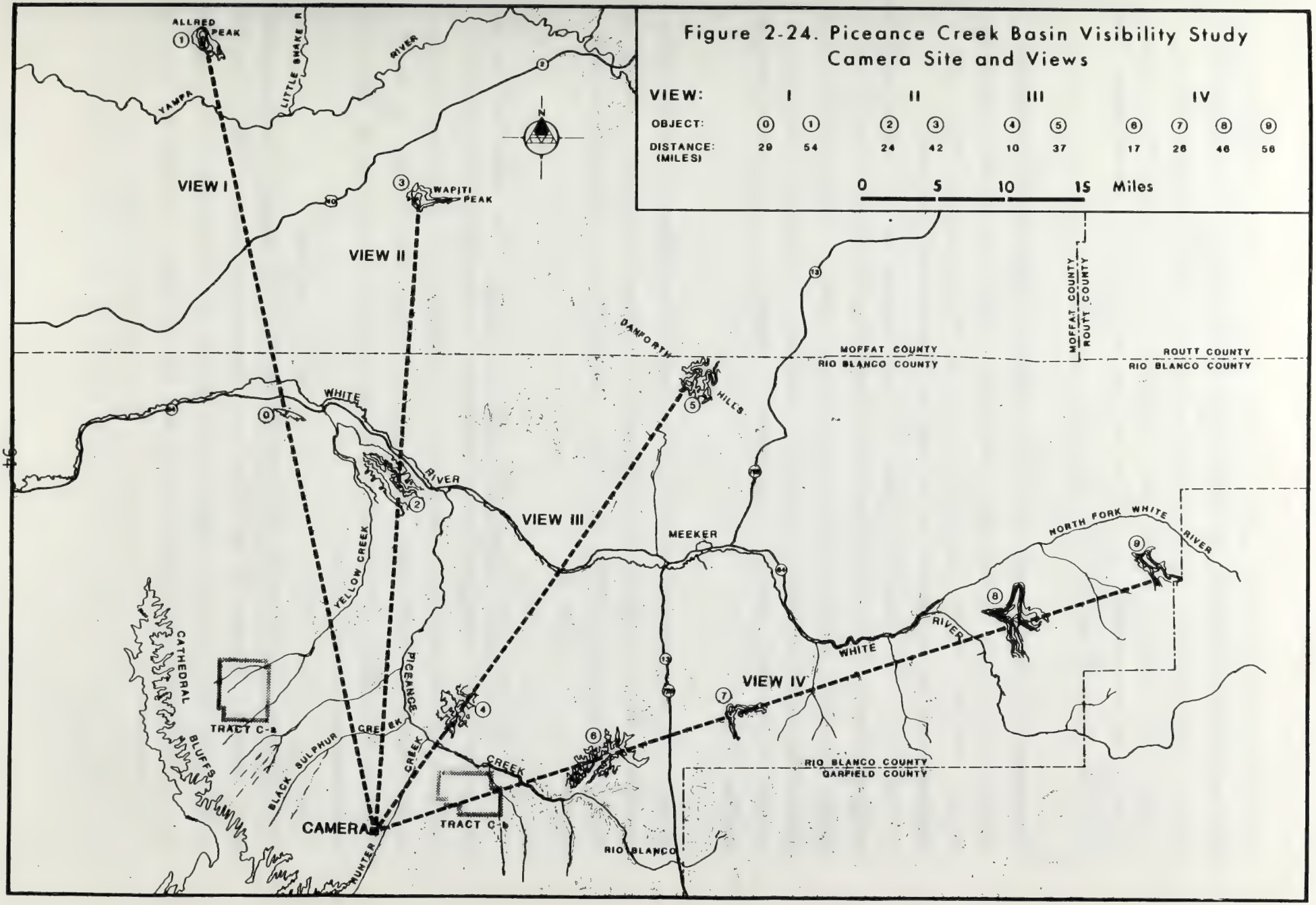


Figure 2-24. Piceance Creek Basin Visibility Study
Camera Site and Views
VIEW: I II III IV
OBJECT: 0 1 2 3 4 5 6 7 8 9
DISTANCE (MILES): 29 54 24 42 10 37 17 26 46 58
0 5 10 15 Miles
ALLRED PEAK
LITTLE SNAKE R
YAMPA RIVER
WAPITI PEAK
VIEW I
VIEW II
VIEW III
VIEW IV
DANFORTH HILLS
MOFFAT COUNTY
ROUTT COUNTY
RIO BLANCO COUNTY
WHITE RIVER
YELLOW CREEK
MEEKER
NORTH FORK WHITE RIVER
CATHEDRAL BLUFFS
BLACK SULPHUR CREEK
PICEANCE CREEK
TRACT C-a
TRACT C-b
CAMERA
HUNTER CREEK
RIO BLANCO
GARFIELD COUNTY

order to prevent inclement weather in November from affecting the monitoring program, the fall schedule was moved forward one month (with the concurrence of the Oil Shale Office). Thus, the fall monitoring began the first week in September and ended the first week in November. Of a possible 560 scheduled visual range measurements during the two seasons, 513 valid measurements were obtained, for a 92 percent data recovery.

Measurements of visual range during the year were occasionally hampered by passing rain or snow showers which restricted visibility and made photography of the views difficult. Accumulations of snow on some objects being photographed required adjustments to be made in their albedo (short-wave reflectivity). The resulting albedo for these objects was estimated using the original albedo of the object modified by the relative contribution of the snow. The albedo values used for the original objects' surfaces and for the additional snow cover were based on the spectral reflectance of snow and various soil types listed in the Handbook of Geophysics and Space Environments (Valley 1975).

Visual range measurements have now been taken over five periods which can be compared: Fall 1975 and Spring 1976, which represent the baseline period; and the Spring and Fall of 1978, 1979, 1980, and 1981, which represent the MDP period.

a. Evaluation of visual range on a daily basis - The computation of a daily mean visual range provides an indication of the prevailing visibility found during the course of a day, with less emphasis on short-term or directional anomalies. Daily mean, maximum, and minimum visual ranges in the Piceance Creek Basin were calculated for each day of monitoring and the results are presented in Table 2-34.

The daily mean visual ranges obtained during 1981 were generally high and were most frequently between 90 and 100 miles, although they varied from 57 to 113 miles. The hourly visual ranges used to compute the daily mean visual ranges for the spring and fall monitoring periods are included in Appendices 2-6.1 and 2-6.3, respectively. Descriptions of visual and meteorological conditions existing on the sampling days are presented as Site Log Sheets in Appendices 2-6.2 and 2-6.4.

Table 2-34. Daily Mean Visual Range (Miles), Piceance Creek Basin, Colorado, Spring and Fall, 1980

	Date	Mean Visual Range	Hourly Min./Max.
Spring	May 14, 1981	101	64/138
	21	57	37/105
	27	86	44/149
	30	70	45/96
	June 2, 1981	74	58/98
	5	90	57/137
	8	110	83/160
	11	99	76/143
	17	65	38/121
Fall	September 3, 1981	100	64/175
	9	95	35/171
	15	82	59/105
	21	68	44/119
	24	81	41/126
	October 6, 1981	76	53/109
	12	91	56/161
	21	91	72/117
	27	77	33/151
	November 4, 1981	113	94/141

Large fluctuations in the mean visual range between consecutive sampling days were common during 1981, with day-to-day variations ranging from 0 to 44 miles. Between May 14 and 21, 1981, for example, the mean visual range decreased from 101 to 57 miles. However, on October 12 and 21, 1981, the mean visual range remained constant at 91 miles. The fluctuations exhibited in 1980 were about the same as comparable periods in the earlier studies. The average change between consecutive sampling days has been between 16 and 18 miles during each of the last four years (1978-1981), but was 28 miles during the baseline period (1975-76).

The daily mean visual range is computed as an average of the visual ranges in each of four views (Figure 2-25). The increases or decreases in mean visual range between consecutive sampling days, evident in Table 2-34, were generally matched by similar increases or decreases in the visual range at each view. These fluctuations, shown in Figure 2-25, illustrate the similar response to changes in visibility which each view exhibited. The correlation between fluctuations in daily mean visual ranges among the views implies that the influences on visibility were widespread and generally uniform in the way they affected visibility.

b. Evaluation of visual range on a monthly basis - Monthly mean visual ranges were calculated from measurements obtained from all the views and hours during each month of monitoring. The monthly mean visual ranges obtained in the Piceance Creek Basin Area during the 1981 spring and fall monitoring periods are listed in Table 2-35. Values obtained during comparable periods in 1975-76, 1978, 1979, and 1980, have been included for review and comparison with the 1981 data.

Monthly mean visual ranges obtained during the four full months of monitoring in 1980 ranged from 79 miles in May to 88 miles in November. Table 2-35 shows that the greatest year-to-year variability in visual range occurs in November, while the smallest year-to-year variability is in October. One explanation for this phenomenon is that October is generally a warm, dry month with fair weather, while November is often the beginning of winter in the Piceance Basin.

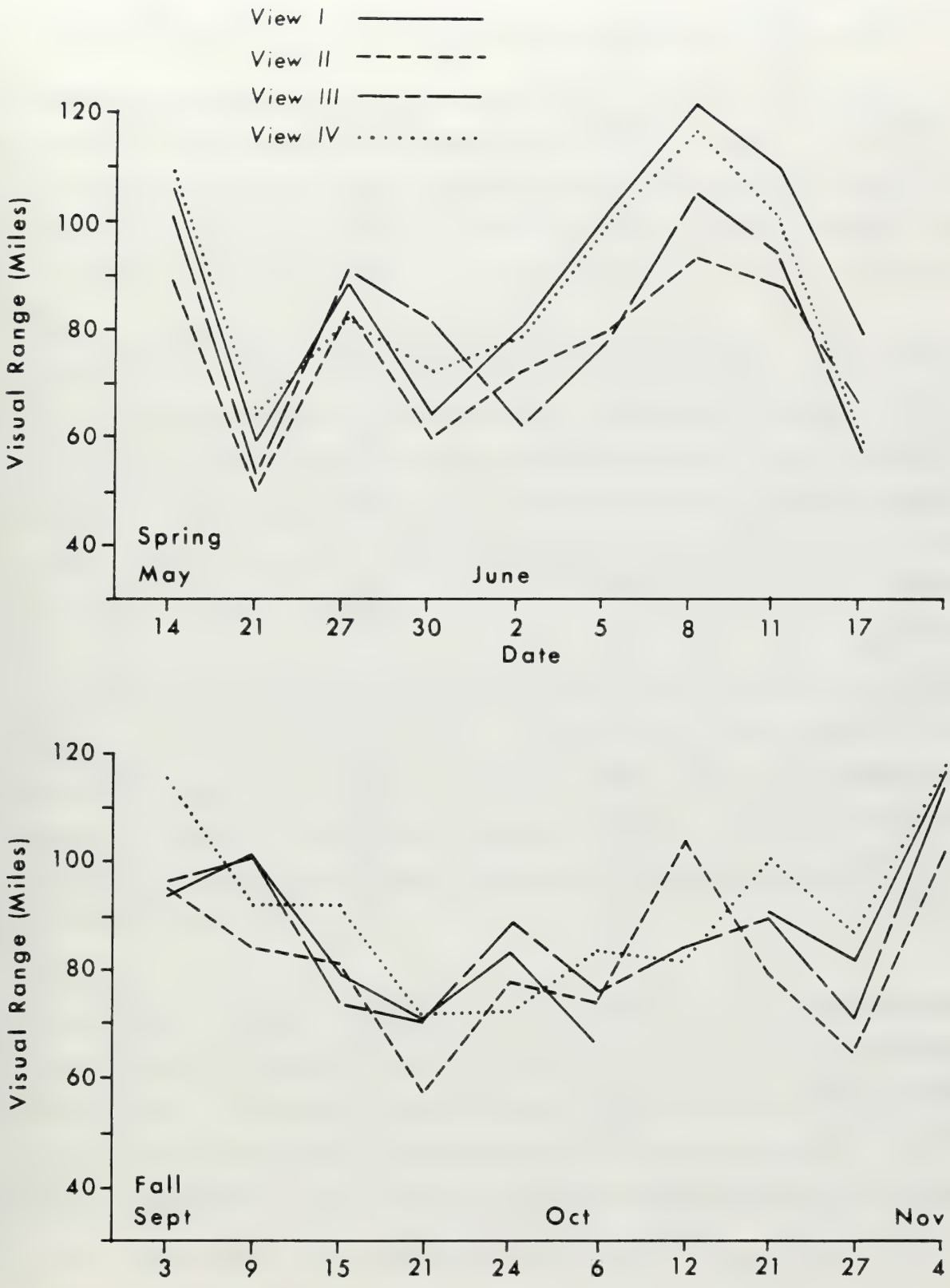


Figure 2-25. Daily Mean Visual Range For Each View, Spring and Fall 1981, Piceance Creek Basin, Colorado

Table 2-35. Monthly Composite Visual Range Comparison (Miles) During Spring and Fall for 1975-1976, 1978, 1979, 1980, and 1981, Piceance Creek Basin, Colorado

Month	Mean[1/]	Maximum	Minimum
April 1979[2/]	67	86	43
April 1978	83	142	21
April 1976	67	138	14
May 1981	79	149	37
May 1980	67	115	22
May 1979	78	154	36
May 1978	74	132	17
May 1976	70	124	27
June 1981	88	160	38
June 1980	83	126	49
June 1979[3/]	85	117	54
June 1976	71	117	45
October 1981	84	161	33
October 1980	83	161	17
October 1979	89	137	50
October 1978	84	130	50
October 1975	89	144	44
November 1980	103	176	53
November 1979	77	132	25
November 1978[4/]	70	121	22
November 1975	99	149	24

[1/] Monthly means are based on approximately five days of photography per month

[2/] Values based on two full days and one partial day of photography

[3/] Values based on two full days of photography

[4/] Values based on one full day and three partial days of photography

This supports earlier findings that meteorological conditions are the overriding factor which affects visibility in the Piceance Creek Basin.

Hourly maximum and minimum visual range measurements for each month are also listed in Table 2-35. The absolute minimum and maximum visual ranges encountered during the five years of sampling were 14 and 149 miles in 1975-76, 17 and 142 miles in 1978, 25 and 154 miles in 1979, 17 and 176 miles in 1980, and 33 and 175 miles in 1981.

c. Evaluation of visual range on a seasonal basis - Visual range measurements were made from May to early July and in October and November 1981 to quantify and characterize the visibility of the area. The selection of these seasons for data collection was based on the results of the initial study (1975-76), which indicated that the seasonal mean visual range was at a minimum during the Spring and at a maximum during the Fall. Visibility data measured during these two seasons in 1981 are compared with data obtained during the four earlier years of record.

The visual ranges obtained within the Piceance Creek Basin during the two seasons in 1981 were generally high; the mean visual ranges were 84 miles during the Spring and 87 miles during the Fall. These and additional statistical descriptors are listed in Table 2-36 for each season and for the comparable seasons in the previous years. The data for 1975-76, however, includes three months per season, although the sampling frequency (once per six days) was identical.

The median is perhaps a better measure of the central tendency of a data set than the mean, since it is unbiased by extreme values. Table 2-36 shows that, over the years, the seasonal mean visual ranges have been close to the median visual ranges. During the baseline period, there was a much lower median visual range in the Spring than in the Fall (67 versus 92 miles). This 25-mile seasonal increase in median visual range during the baseline has not been duplicated during the four-year MDP monitoring program -- the average MDP median visual ranges have been 78 miles in the Spring and 86 in the Fall. This change has been primarily caused by a large increase in the median Spring

Table 2-36. Seasonal Composite Visual Range Comparison (Miles During Spring and Fall for 1975-1976, 1978, 1979, 1980, and 1981, Piceance Creek Basin, Colorado

Season	Mean	Maximum	Minimum	Fifth Percentile	Median
Spring 1981	84	160	37	46	83
Spring 1980	78	126	22	45	78
Spring 1979	77	154	36	46	72
Spring 1978	79	142	17	43	81
Spring 1975-76	69	138	14	39	67
Fall 1981	87	175	33	55	83
Fall 1980	93	176	17	55	90
Fall 1979	84	137	36	42	87
Fall 1978	80	130	22	43	82
Fall 1975-76	91	149	24	45	92

visual ranges from the baseline to the MDP period, but was also due to a decrease in the the Fall visual ranges over the same period. It is difficult to find a plausible reason for these two conflicting trends, and in any event they are probably not statistically significant. This analysis points out that it is very difficult to obtain representative visibility data, particularly over a short time period (i.e., the baseline period). Because of the large day-to-day variability in visual range (caused primarily by meteorological conditions), a large data base is needed to obtain a valid data set.

The seasonal composite visual range summary for the Spring and Fall for 1981, 1980, and the 1975-76 baseline period is shown in Figures 2-26 through 2-28. The figures illustrate that there is a shift toward higher visual ranges from Spring to Fall in 1981, 1980, and 1975-76. As discussed above, there was a more pronounced shift toward higher visual ranges in the Fall during 1975-76.

Table 2-37 shows the seasonal visual range summary for each view during all five years of record. The table indicates that the mean visual range data for the Spring of 1978, 1979, 1980, and 1981 are relatively similar for each of the four views. The Spring of the baseline year (1975-76), in comparison, had similar ranges for each of the four views, but these were generally lower than later years. During the Fall, however, the data from all five years compare fairly well, with no consistent trend. The most striking fact is the wide scatter of mean visual ranges in the Fall, both among views in a year, and among years for any given view. These year-to-year variations are most likely due to changes in the meteorological conditions.

d. Evaluation of visual range on an annual basis - Visual range measurements made during 1981 were generally high with an annual mean visual range of 86 miles. This compares with an annual mean of 85 miles in 1980, 80 miles in 1979, and 79 miles during the first two years of study (Table 2-38). The range of values obtained was also quite high; visual ranges in 1981 varied from 33 miles to 175 miles. The distribution of these values is presented in Figure 2-29. Distributions for 1980 and 1975-76 are presented in Figures 2-30 and 2-31 for comparative purposes. These figures show that in both 1980 and 1981

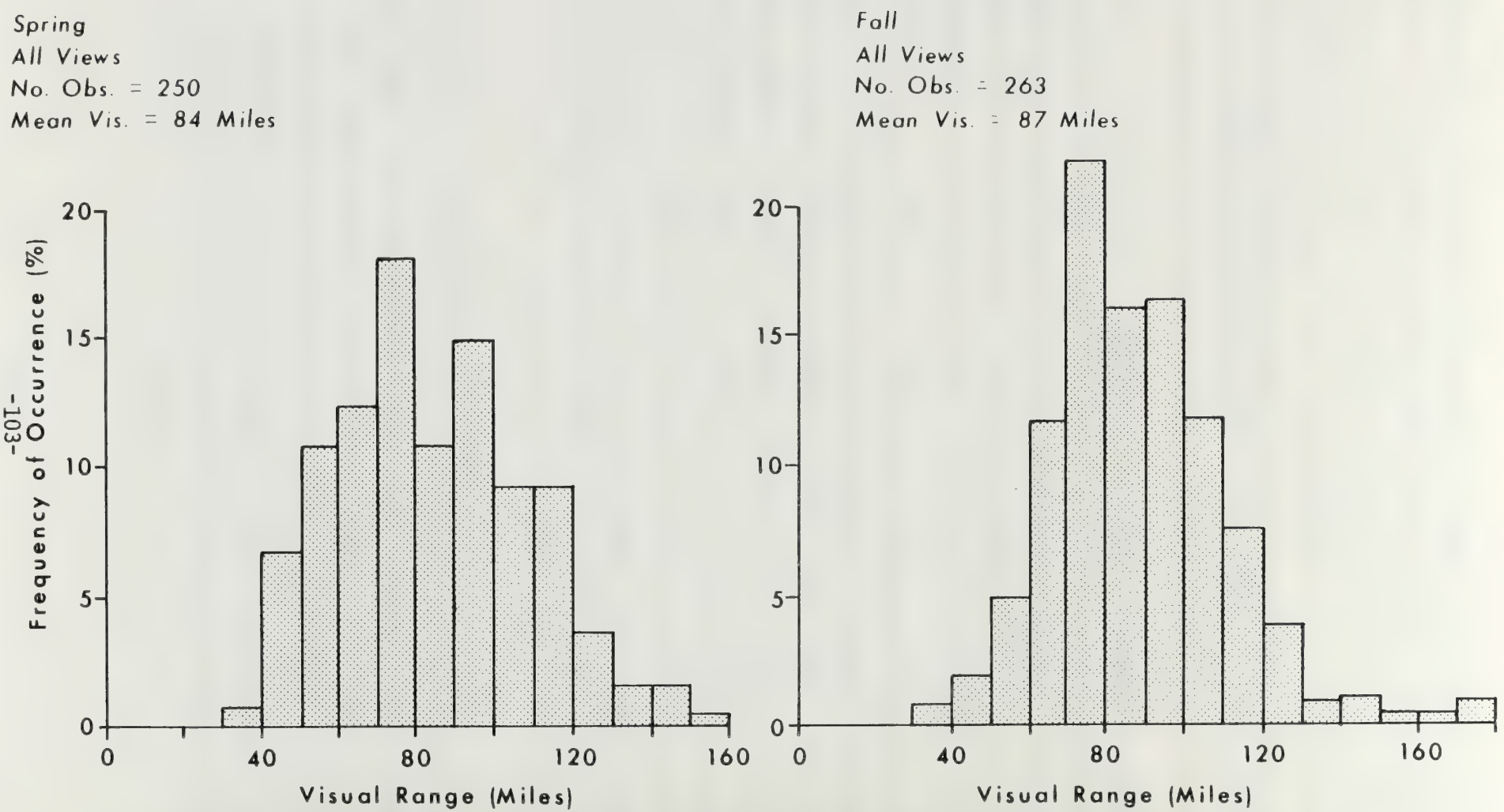


Figure 2-26. Seasonal Composite Distribution of Visual Range, Spring and Fall 1981, Piceance Creek Basin, Colorado

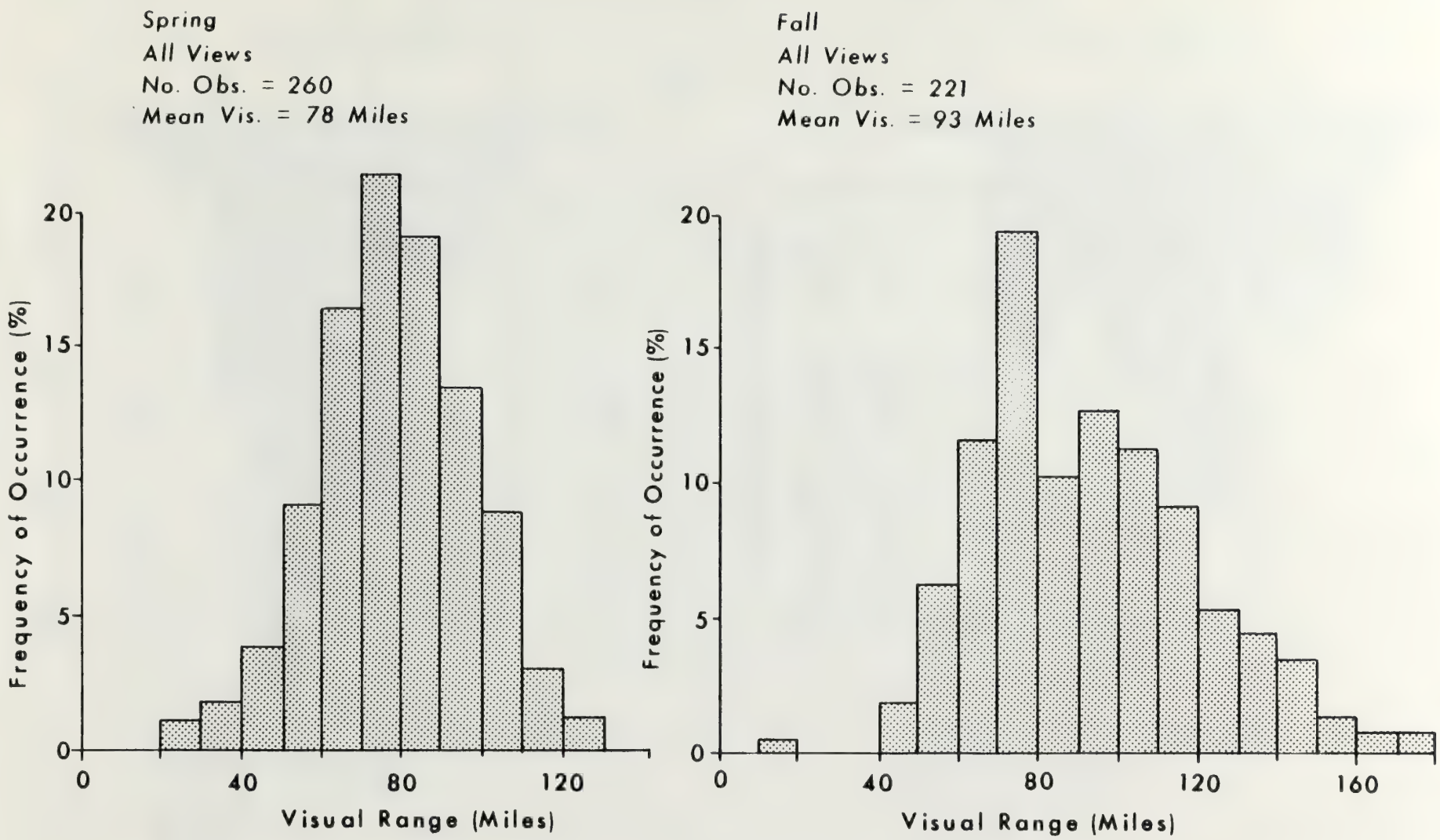


Figure 2-27. Seasonal Composite Distribution of Visual Range, Spring and Fall 1980, Piceance Creek Basin, Colorado.

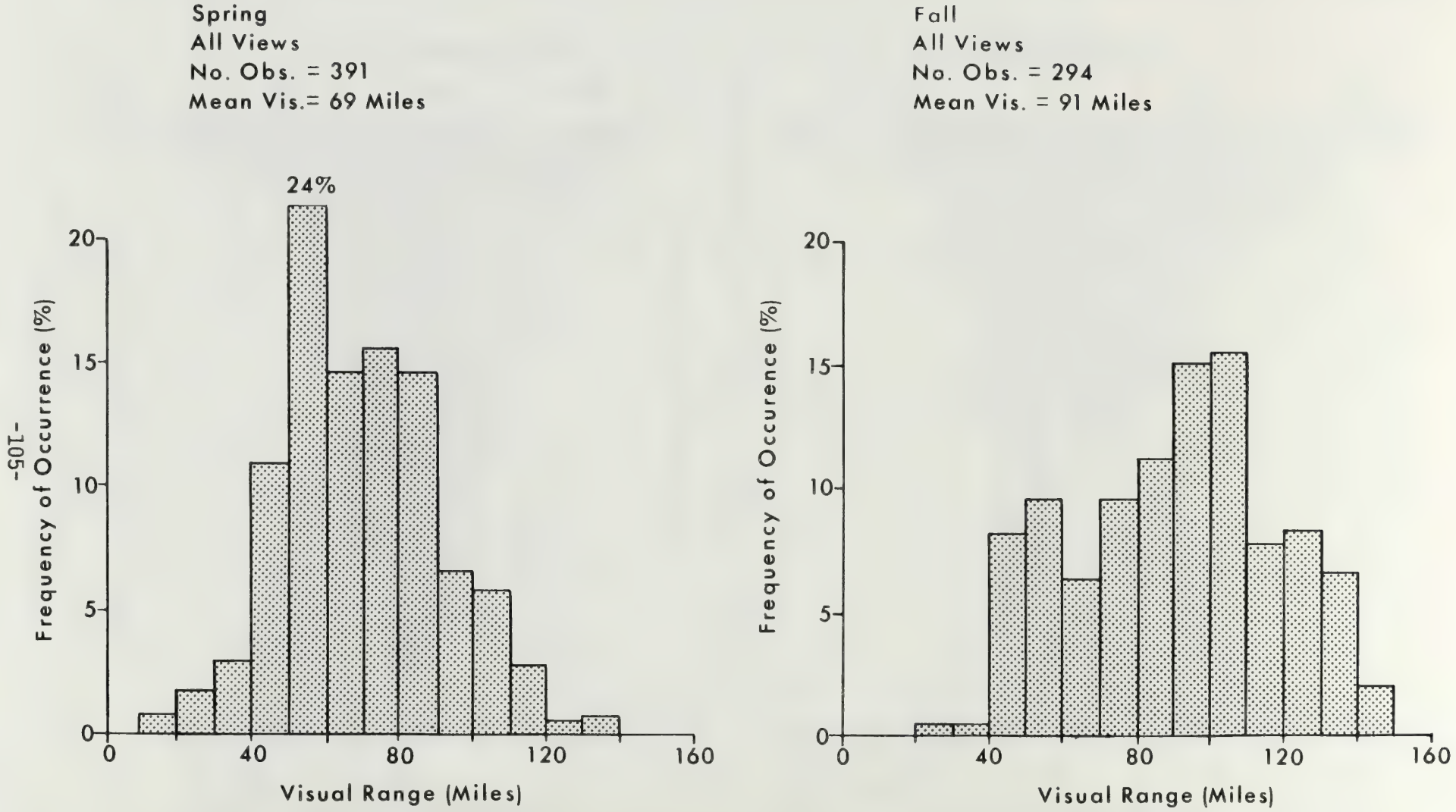


Figure 2-28. Seasonal Composite Distribution of Visual Range, Fall 1975 and Spring 1976, Piceance Creek Basin, Colorado.

Table 2-37. Seasonal Visual Range Summary (Miles) for Five Periods: Fall 1975 and Spring 1976, Spring and Fall 1978, Spring and Fall 1979, Spring and Fall 1980, and Spring and Fall 1981, in the Piceance Creek Basin, Colorado

		Mean					Hourly Maximum					Hourly Minimum				
	View	1975-76	1978	1979	1980	1981	1975-76	1978	1979	1980	1981	1975-76	1978	1979	1980	1981
Spring	I	74	81	81	80	90	118	126	139	126	160	39	51	36	29	44
	II	63	73	73	72	76	113	112	129	102	118	32	32	43	35	37
	III	67	77	82	76	81	118	132	154	119	149	14	17	44	22	38
	IV	73	84	74	85	87	138	142	141	120	138	27	35	39	37	45
Fall	I	93	87	84	92	88	149	130	126	161	151	37	58	41	45	53
	II	77	76	76	83	82	142	102	132	156	161	42	55	41	47	43
	III	92	71	82	88	87	146	103	128	138	150	24	22	25	17	33
	IV	101	86	94	111	92	148	125	137	176	175	48	31	36	56	35

Table 2-38. Annual Visual Range Summary (Miles) for Five Periods: 1975-76, 1978, 1979, 1980, and 1981 in the Piceance Creek Basin, Colorado

View	Mean					Hourly Maximum					Hourly Minimum				
	1975-76	1978	1979	1980	1981	1975-76	1978	1979	1980	1981	1975-76	1978	1979	1980	1981
I	83	83	83	85	89	149	130	139	161	160	31	51	36	29	44
II	69	74	74	77	79	142	112	132	156	161	31	32	41	35	37
III	78	74	82	82	84	149	132	154	138	150	14	17	25	17	33
IV	85	85	83	97	90	148	142	141	176	175	22	31	39	37	35
Composite	79	79	80	85	86	149	142	154	176	175	14	17	25	17	33

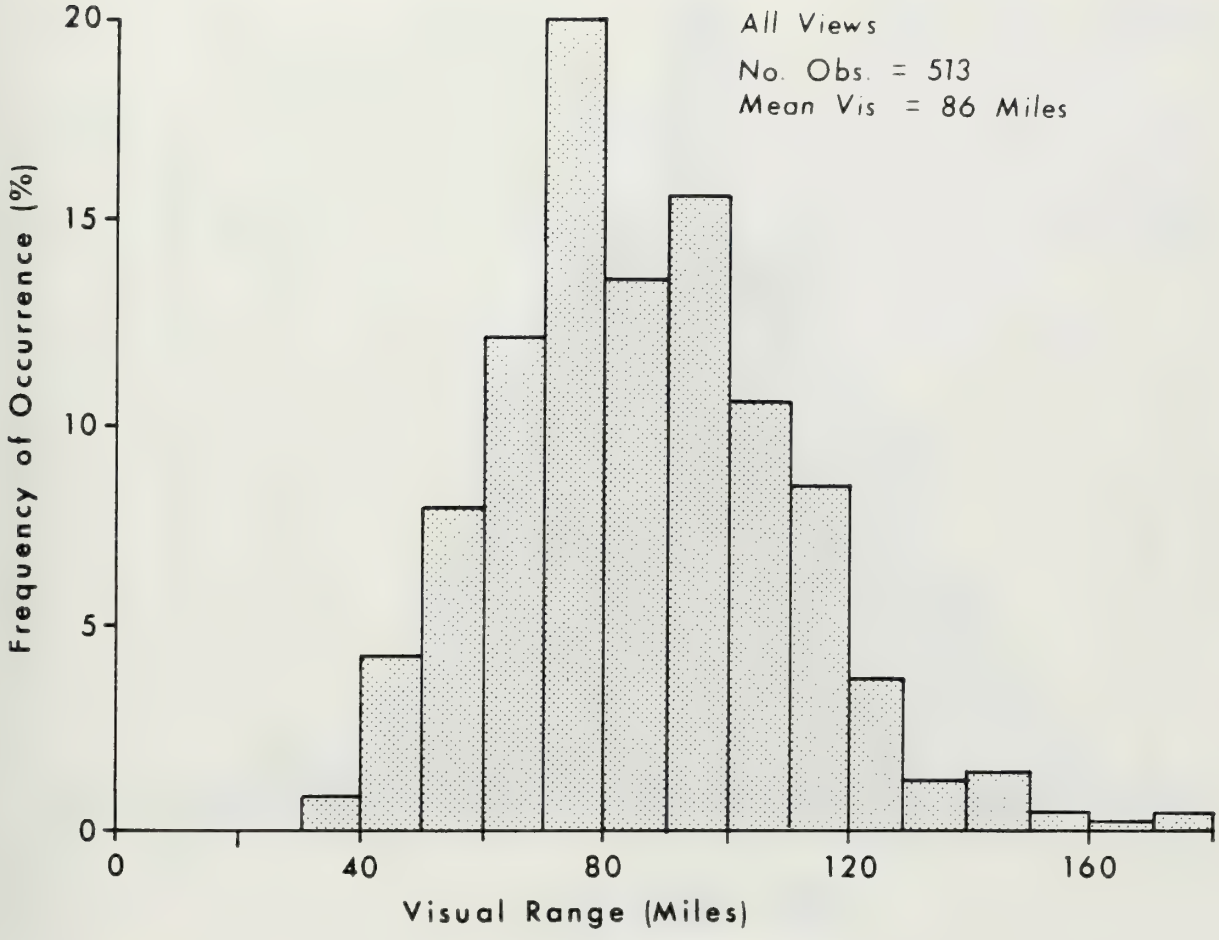


Figure 2-29. Annual Composite Distribution of Visual Range, 1981, Piceance Creek Basin, Colorado

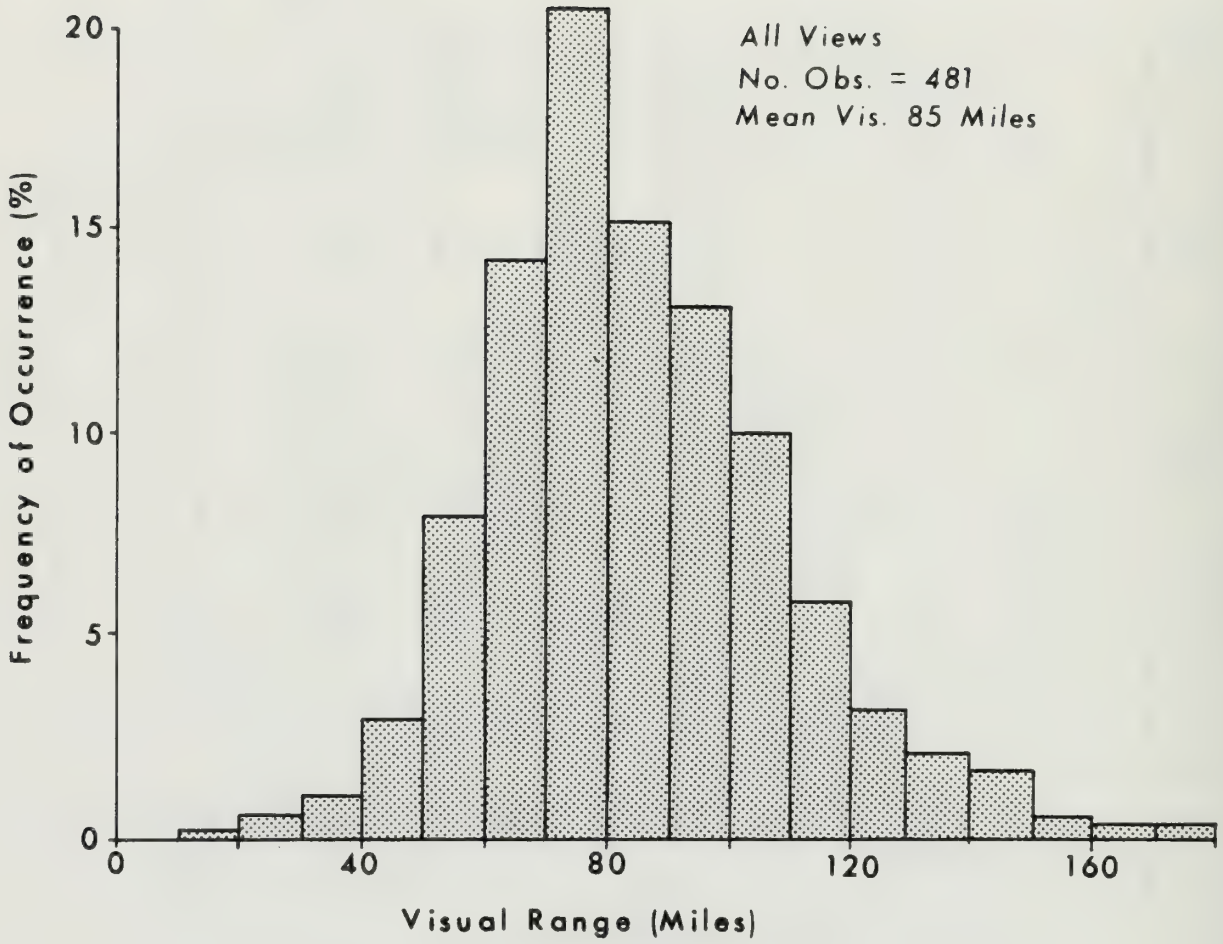


Figure 2-30. Annual Composite Distribution of Visual Range, 1980, Piceance Creek Basin, Colorado

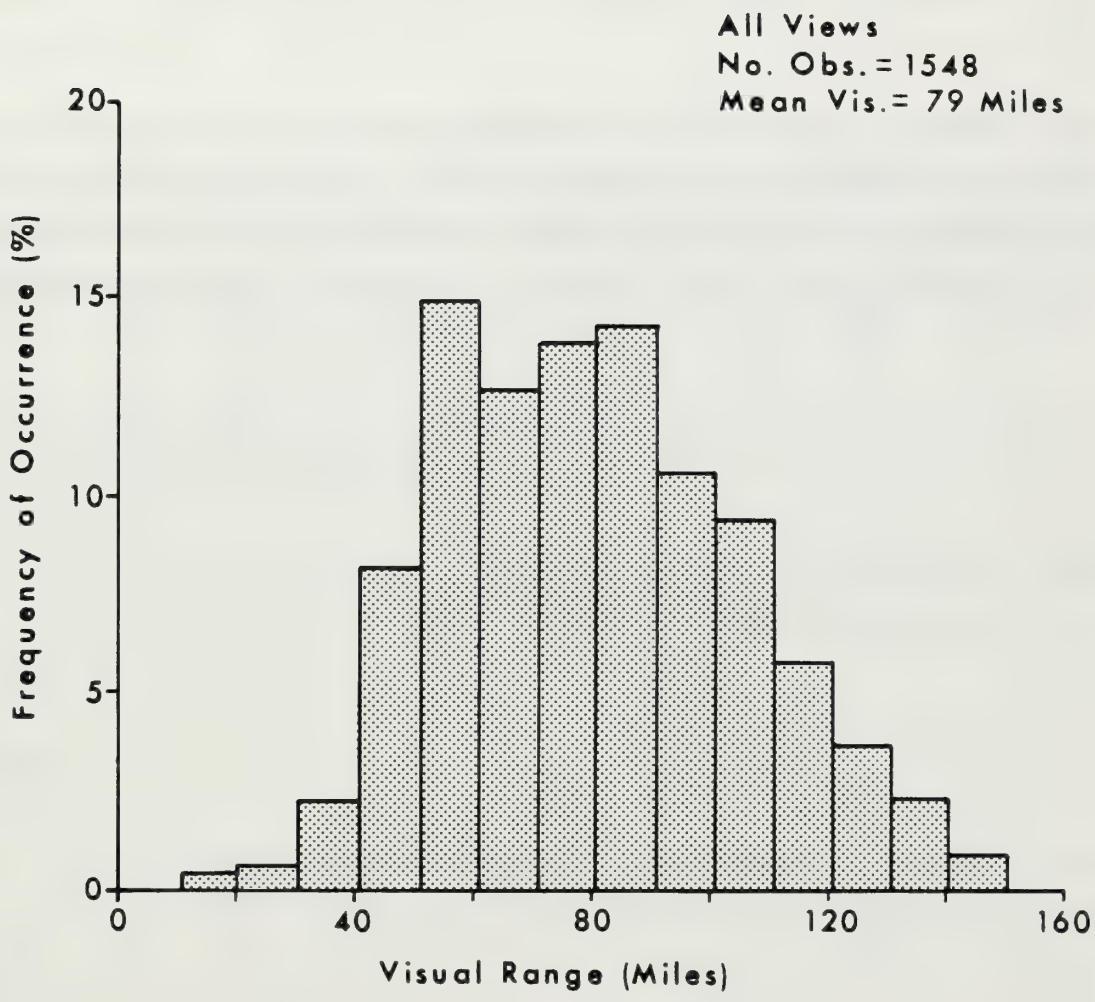


Figure 2-31. Annual Composite Distribution of Visual Range, 1975-76, Piceance Creek Basin, Colorado

the most frequent visual range was 70-80 miles, by a distinct margin. However, in 1975-76, the visual ranges were distributed more evenly between 50 and 90 miles.

Hourly maximum visual ranges obtained during the current year varied among the views; maximum values ranged from 150 miles in View III to 175 miles in View IV. Hourly minimum visual ranges varied somewhat less among the views than the maximum values, ranging from 33 miles in View III to 44 miles in View I.

This summary of the visibility data has shown that there has been no consistent change in the mean visual range measured at the visibility monitoring site since the original study was conducted in 1975-76. A review of the data indicates there is at least as much variation in visual range among the views and between sampling days as there is between monitoring years.

2.6 NOISE

Development activities on Tract C-a will result in increased noise levels in the area. In order to assess the potential effects of these increased noise levels, it will be necessary to identify the sources of the noise and the intensity of noise levels at various distances from these sources. The noise survey is designed to provide these data.

1. Objectives

Regulations regarding allowable noise levels have been promulgated for the safety and well being of humans. None of the existing regulations apply to effects of noise on wildlife, although some research has been conducted in this area (EPA 1971). The following are the objectives of the environmental noise program:

- Provide a data base on relative noise levels at various distances from sources on the tract
- Provide data for use by wildlife biologists in assessing the overall impacts of tract development on wildlife behavior and use of the study area.

2. Methods

In order to acquire the necessary noise level measurements, sound level readings are taken once each quarter at strategic monitoring sites around the tract development area. During the period of study, two noise surveys were made with a General Radio Model 1565-D sound level meter, which has a threshold of 30 dBA. Noise measurements were taken at 16 monitoring sites on August 17 and November 13, 1981.

The noise monitoring sites are arranged in a configuration of concentric circles at various distances from the area of activity out to the borders of Tract C-a, as described in Table 2-39. One other reading was taken in close proximity to the headframe at the main process area for an indication of highest noise levels.

Table 2-39. Locations of Environmental Noise Monitoring Sites, Tract C-a

Site Number	Locations/Descriptions
1	Top of knoll N.E. of Hunting Camp, E. of road down to Corral Gulch
2	South side of site access road, 20 ft S.W. of "Hill" signs
3	N.E. corner of intersection of Airplane Ridge Road and tank access road
4	South side of Corral Gulch Road at fence corner slightly past power line
5	100 ft. S.E. from well CE-707, on line between survey point and headframe
6	Northwest of Well TO-2 outside of fence, 10 ft W. of survey point
7	North side of Corral Gulch Road at Well G-S 4-5 on top of road cut
8	West side of Wolf Ridge road on small knoll directly across from entrance to Well G-S 6 and trailer camp
9	North side of fenced area at Well TO-1 near entrance
10	South side of Box Elder Gulch Road at N.E. fence corner for Well AM-3
11	North side of Corral Gulch Road at turn-around area, across from U.S.G.S. stream gauging station
12	South side of road to Met. Site #1, 0.1 mile from power line crossing and S.W. corner of well G-S 1
13	North side of Wolf Ridge Road, N.E. corner of road to Well G-S 10
14	South side of Wolf Ridge Road at Tract C-a boundary line
15	East side of road, 0.15 mile north of Met. Site #2 access road
16	North of County Road 24 at intersection of Wolf Ridge Road
A	Approximately 30 ft east of main shaft headframe

The methods followed in the collection of noise data were described in MDP Monitoring Report 3 (RBOSC 1979).

3. Results and Discussion

Sound level readings taken during the two surveys are shown in Tables 2-40 and 2-41. The highest average decibel levels were 67 dBA in the August survey and 70 dBA in the November survey. Both of these readings were obtained at the monitoring site near the headframe, which is the focal point of onsite activity. Most of the noise levels measured in the August survey were below the instrument detection level (30 dBA). Background noise levels were reached when readings were taken at distances greater than about one mile from the MIS process site. Exceptions to background noise were noted when there were aircraft passing overhead, vehicular traffic, or some other activity, such as an oil drilling rig operating near the monitoring site.

Noise levels taken during these two surveys were generally comparable to those taken during the previous quarterly noise surveys. The potential for wildlife disturbances due to noise of this magnitude is anticipated to be small.

Table 2-40. Environmental Sound Level Measurements Tract C-a, August 17, 1981

Site	Time	Wind	Sound Level Measurements (dBA, Slow Response) (20 sec range) 1	2	3	4	5	Sound Level Range (dBA)	Sound Level Average (dBA)[1/]	Remarks
A	0827	Calm	66-68	66-69	66-68	65-68	65-68	65-69	67	Process compressor, Traffic
1	0838	0-3/E	35-42	35-45	36-42	35-37	35-70	35-70	41	Heavy equipment, helicopter
2	1201	0-7/E	33-37	32-45	32-37	31-42	<30-43	-	-	Heavy equipment, traffic
3	1151	2-7/S	34-37	33-37	36-39	36-42	36-42	33-42	37	
4	0959	0-3/E	30-33	30-31	31-36	<30-32	30-33	-	-	
5	0921	0-4/E	<30	<30	<30	<30	<30	-	-	
6	0932	0-4/E	<30	<30	<30	<30	<30	-	-	
7	1011	0-4/E	30-32	30-34	<30-33	<30-31	<30-32	-	-	
8	1030	1-5/E	<30	<30	<30	<30	<30	-	-	
9	1138	2-7/E	<30	<30	<30	<30-38	31-37	-	-	
10	1128	1-6/E	<30-33	<30-32	<30-31	<30-32	<30-32	-	-	
11	0949	0-2/E	30-37	30-38	30-39	<30-34	<30	-	-	
12	0909	0-3/E	<30	<30	<30	<30	<30	-	-	
13	1041	2-5/E	<30-34	<30	<30	<30	<30	-	-	
14	1049	0-3/E	<30-36	<30-31	<30-34	<30	<30-35	-	-	
15	1100	1-5/E	<30	<30	<30-31	<30-32	<30	-	-	
16	1027	1-5/E	39-52	34-41	31-37	30-45	<30-35	-	-	Process Compressor, Jet
A	1208	1-5/E	66-68	67-69	67-68	66-68	66-69	66-69	67	Process Compressor, Vent Shaft

[1/] Representative sound level averages cannot be computed in some instances because measurements were below the minimum threshold of the instrument

Table 2-41. Environmental Sound Level Measurements Tract C-a, November 13, 1981

Site	Time	Wind	Sound Level Measurements (dBA, Slow Response) (20 sec range) 1	2	3	4	5	Sound Level Range (dBA)	Sound Level Average (dBA)[1/]	Remarks
A	0934	Calm	69-72	68-72	69-72	67-72	67-70	67-72	70	Process compressor
1	0953	Calm	47-52	44-50	47-51	48-52	48-52	44-52	49	Process compressor, Jet
2	1138	0-3/W	43-56	40-51	41-54	40-50	33-39	33-56	45	Process compressor, grader
3	1132	2-5/W	30-33	30-35	31-38	32-38	30-33	30-38	33	Jet
4	0918	Calm	38-44	37-47	36-43	40-47	40-49	36-49	42	Job Noise
5	0848	Calm	32-38	30-33	31-34	31-36	31-35	30-38	33	Job Noise
6	0857	Calm	33-41	34-49	32-39	34-37	36-40	32-41	37	Job Noise
7	0925	Calm	39-42	37-43	37-41	40-43	35-44	35-44	40	Job Noise
8	1009	3/W	<30-31	<30-32	<30	<30-32	<30-32	-	-	
9	1105	0-5/W	<30	<30	<30	<30	<30	-	-	
10	1114	0-5/W	<30-40	<30-36	<30-42	<30-38	<30-35	-	-	
11	0911	Calm	<30	<30	<30	<30	<30	-	-	
12	0838	Calm	35-40	33-40	32-37	35-38	36-39	32-40	37	Job Noise
13	1017	2-10/W	<30-32	<30-42	<30-36	<30	<30-42	-	-	Wind
14	1051	5-10/SW	30-37	<30-34	<30-38	<30-32	<30-34	-	-	Wind, Jet Joise
15	1028	5-10/SW	34-48	35-44	30-43	<30-38	<30	-	-	Wind, Jet Noise
16	1124	2-5/W	<30-34	30-45	<30-35	30-35	<30-37	-	-	Traffic, Jet Noise
A	1146	2-5/S	63-68	63-68	63-68	63-67	63-68	63-68	65	Process Compressor, Job Noise

[1/] Representative sound level averages cannot be computed in some instances because measurements were below the minimum threshold of the instrument

2.7 SUMMARY

Both air quality and meteorological data were collected during the reporting period. The major event affecting air quality within this period was the burning of Retort 1 from June to December. The maximum concentration of sulfur dioxide (the major air pollutant of concern released from the retort) measured during the burn was 0.047 ppm at Site 1. Since this sulfur dioxide concentration was measured under easterly winds (which would transport the stack emissions in the direction of Site 1), it is quite likely that this measurement resulted from the Retort 1 burn. Apparently, sulfur dioxide emissions from the retort are not transported into Corral Gulch, because no values of sulfur dioxide above the background level were detected at Site 3 during the Retort 1 burn.

A supplementary sulfur dioxide monitoring program using grab bag samples was carried out during October, when emissions from the retort were temporarily diverted from the emissions control system to the flare stack. (A detailed report of this program is given in Section 6.7). The highest sulfur dioxide concentration measured during this supplementary monitoring was 0.12 ppm (260 μ/m^3). This is one-half of the 3-hr Class II increment, but is not directly comparable because this was an instantaneous grab bag sample. Sulfur dioxide concentrations at the same location were 40 percent of this value an hour earlier, and near background levels an hour later.

The ozone concentrations found in the vicinity of the tract varied from 0.001 to 0.073 ppm, well below the National Ambient Air Quality Standard (NAAQS) for ozone of 0.12 ppm. The diurnal cycle of ozone concentrations at Site 3 was greater than at Site 1. The larger cycle at Site 3 results from nighttime inversions which develop within the gulch in which Site 3 is located. The inversions effectively seal off the gulch from exchange with the rest of the atmospheric boundary layer, allowing ozone destruction reactions to reduce the ambient ozone concentrations at night.

The source of the relatively high ozone concentrations measured at the tract has not been definitely identified, although these concentrations have been found to be typical of many other remote locations. There has been no evidence of local photochemical production from either natural or anthropogenic sources.

Total suspended particulates (TSP) did not exceed the NAAQS during the current year. Multiple and stepwise regression analyses were carried out on the particulate data, using a combination of meteorological and site activity variables. The highest correlations were found using the annual rather than the seasonal TSP data sets. Approximately two-thirds of the variability of TSP concentrations in the annual data sets could be explained by the meteorological and site activity variables. This is very similar to the results of regression analyses performed for the three previous years.

Site activity parameters ranked no higher than third in explaining the variability of TSP concentrations, and contributed only minor improvements to the regression analyses. Temperature was by far the most successful predictor, largely because it has an annual cycle similar to the TSP data, and it serves as an indicator variable for other important parameters, such as soil moisture.

Review of the meteorological data from the current year revealed that 1981 was slightly warmer and considerably wetter than previous years. Precipitation at the tract totalled approximately 17 inches during the current year. The annual temperature range of 50 C (-20 C to +30 C) measured during the current year at Site 1 is typical of continental sites. Wind speed at the tract has been relatively low, reaching a maximum of 26 mph at the 10-m level at Site 1. Winds have been predominantly out of the west and southwest.

The 1981 visibility monitoring program indicated a slight increase in visual ranges in the Piceance Creek Basin. The mean annual visual range during 1981 was 86 miles, which compares with visual ranges of 85 miles measured in 1980, and 79 and 80 miles measured during the three earlier years of monitoring. There is a large day-to-day variability in the visual range, but this is primarily a result of widely varying meteorological conditions. The maximum visual range measured in 1981, 175 miles, was the second highest value in the five years of monitoring. Visual ranges of at least 142 miles have been recorded during each of the years. These values approach the theoretical limit of visual range in the atmosphere.

Two noise surveys were taken during the reporting period. The measured sound levels generally ranged from less than 30 dBA (the threshold of the instrument) to 50 dBA, except near the main construction area (adjacent to the headframe), which averaged 67 dBA. If the measurements taken near the main construction area are excluded, these sound levels are comparable to data taken during the baseline period.

LITERATURE CITED

Hess, Seymour L. 1959. Introduction to Theoretical Meteorology, Holt, Rinehart and Winston, NY.

Nuclear Regulatory Commission (NRC). 1972. Onsite meteorological programs regulatory guide 1.23.

Rio Blanco Oil Shale Project (RBOSP). 1976. Detailed Development Plan for Tract C-a. Gulf Oil Corp. and Standard Oil Co. (Indiana).

Rio Blanco Oil Shale Company. 1978. Modular development phase monitoring report 1, September-November 1977. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1978A. Modular development phase monitoring report 2, December 1977 - May 1978. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1979. Modular development phase monitoring report 3, December 1977 - November 1978. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1979A. Modular development phase monitoring report 4, December 1978 - May 1979. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1980. Modular development phase monitoring report 5, December 1978 - November 1979. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1981. Modular development phase monitoring report 7, December 1979-November 1980. Gulf Oil Corp. and Standard Oil Co. (Indiana).

U.S. Environmental Protection Agency. 1971. Effects of Noise on Wildlife and Other Animals, Memphis State University.

_____. 1978. Air quality criteria for ozone and other photochemical oxidants, EPA-600/8-78-004.

Valley, Shea L., Handbook of Geophysics and Space Environments, Air Force Cambridge Research Lab., p 7-4.

SECTION 3

TERRESTRIAL STUDIES

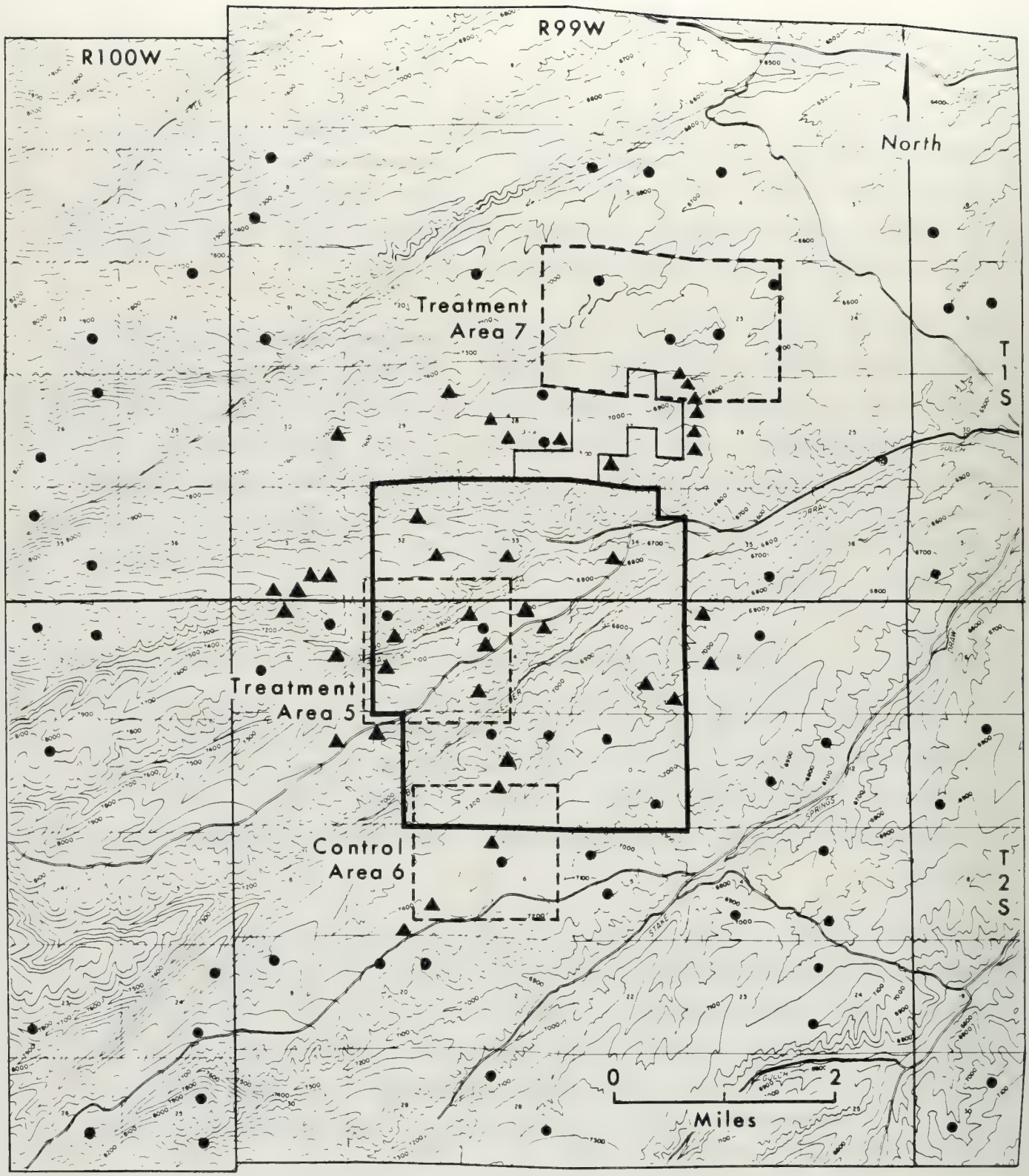
3.0 INTRODUCTION

The objective of the Terrestrial Studies portion of the MDP Environmental Monitoring Program is to conduct monitoring required by the environmental stipulations in the Tract C-a lease, and to detect and evaluate (in terms of development-related impact) any changes in the vegetative or faunal components of the terrestrial ecosystems on or near Tract C-a.

The sampling program associated with the Terrestrial Studies is geared to the seasonal cycles of the ecosystems involved. During the 1981 reporting year, monitoring of phytosociology, range productivity and utilization, browse condition and utilization, vegetation mapping and stress, small mammals and avifauna abundance, mule deer density, mule deer road kill, and feral horse abundance was conducted. The results of these monitoring activities are reported in this section of MDP 9. The locations of the Terrestrial Studies monitoring sites are shown in Figure 3-1.

The design of the Terrestrial Studies program is based on current knowledge of Tract C-a ecosystems and RBOSC project development plans. As the development of Tract C-a is a pioneering effort, such development plans are subject to frequent modification. The basic knowledge of Tract C-a ecosystems is also increasing. These factors result in frequent changes to the Terrestrial Studies portion as well as other components of the MDP Environmental Monitoring Program.

Terrestrial data presented in this report were collected according to the methods described in the Modular Development Phase Environmental Monitoring Program Scope of Work, Revision 6.1 (RBOSC 1981a). All data were verified in compliance with RBOSC quality control procedures, which included supervisory verification of field data sheets, laboratory analysis, and data management processes. Documentation supporting these quality control procedures appears in the RBOSC Quality Assurance files.



- Mule Deer Pellet Group Sample Unit
- Range-Browse, Productivity & Utilization Study Site
- Intensive Study Sites

Figure 3-1. Terrestrial Ecology Monitoring Sites.

3.1 VEGETATION, RANGE, AND BROWSE

A. Vegetation Mapping and Stress

1. Objectives

Construction and operation of Tract C-a facilities may affect the local distribution and/or condition of vegetation types. Therefore, these vegetation mapping and stress studies are designed to monitor the distribution of plant communities on Tract C-a and adjacent areas in order to determine large-scale changes resulting from MDP development, to identify stress conditions, and to document changes in the plant communities over time.

2. Methods

Documentation of plant community distribution and condition is accomplished via aerial photography (color, black-and-white, and color infrared). Methods used in these studies are detailed in MDP Reports 1 and 4 (RBOSC 1978a, 1979b).

During June 1981, black-and-white aerial photographs were taken over Tract C-a and an approximate five mile boundary. These photographs (approximate scale, 1 inch = 2,000 feet) were compared to the baseline Vegetation Types Map and the 1978 color aerial photographs to ascertain changes in plant community distribution.

Color infrared (CIR) aerial photography (scale, 1 inch = 500 feet) was also conducted during June 1981 for the vegetation stress assessment.

Areas included in the 1981 CIR assessment include the following:

- Corral Gulch (Water Gulch and Dry Fork) from one mile west of Tract C-a to Yellow Creek
- Big Duck Creek from Cottonwood Springs to Yellow Creek

- Yellow Creek from the confluence of Stake Springs Draw and Corral Gulch to the White River

3. Results and Discussion

The comparison of 1981 black-and-white aerial photography with the baseline Vegetation Types Map and with 1978 color aerial photographs did not result in the identification of any areas where plant community distribution has changed markedly as a result of Tract C-a development activities. However, tract-related disturbance for various construction and dewatering/reinjection activities eradicated small portions of Sagebrush and Pinyon-Juniper communities. Of the 31 areas of disturbance noted within Tract C-a plus a five mile perimeter, 13 were related to RBOSC activity, 16 to oil and gas exploration and/or development. The two remaining areas of disturbance included the sand and gravel operation at 84 Ranch and the C.S.U. experimental revegetation plots.

The increased abundance of grass species and corresponding decrease in living sagebrush individuals in Corral Gulch (approximately 0.75 miles east of Meteorological Site 3) was not readily apparent on the black-and-white photographs. However, this area is evident on CIR photographs from 1974, 1979, 1980, and 1981 (RBOSC 1980, 1981b). Although the analysis of the 1981 CIR photographs is not available for inclusion in MDP Monitoring Report 9, it will be included in subsequent reports. Preliminary observations of 1981 CIR photography and on site inspection indicate that there has been little change since 1979. RBOSC will continue to track changes which may occur in this particular location.

B. Browse

1. Objectives

Tract C-a development will reduce browse availability and therefore may affect the distribution of deer in the vicinity of Tract C-a. The browse condition and utilization studies are designed to provide browse use information for areas adjacent to Tract C-a development.

2. Methods

The methods for collection of browse data were described in RBOSC MDP Monitoring Reports 1 and 2 (RBOSC 1978a, 1978b). The transect numbers and locations are the same as those for range productivity studies except that ten new sites have been added (five each in the Pinyon-Juniper and Sagebrush vegetation types) during the reporting period (Figure 3-1). With the exception of a dead juniper (Juniperus osteosperma) on Transect PJ-12 which had been mislabeled as a pinyon pine (Pinus edulis), the plants censused in 1981 were the same ones assessed for browse condition in previous sampling periods. Browse condition was assessed between April 28 and May 15, 1981.

Leader use values (%) for each species within the three vegetation types were arcsine transformed and analyzed using the following two-way analysis of variance (ANOVA).

Source of Variation	Degrees of Freedom	F-Test
A. Year (phase of development)	a-1	A/D
B. Transect	b-1	B/D
C. Year x Transect	(a-1)(b-1)	C/D
D. Error	ab(n-1)	
Total	abn-1	

Leader use values (%) from the 1981 sampling period for each species within the three vegetation types were also arcsine transformed and analyzed by the following one-way ANOVA.

Source of Variation	Degrees of Freedom	F-Test
A. Transect	a-1	A/B
B. Error	a(n-1)	
Total	an-1	

3. Results and Discussion

Data obtained during the 1981 sampling period are summarized in Table 3-1 and presented in their entirety in Appendix 3-1.1 of MDP Monitoring Report 8 (RBOSC 1981c).

a. Mixed Brush - The 1981 data set for the mixed brush vegetation type includes nine transects as opposed to ten, as in previous years. Analyses of 1980 range production data and reevaluation of the general site conditions and species composition for Transect 6 indicated that this transect would be categorized more appropriately in the Pinyon-Juniper vegetation type rather than in the Mixed Brush type. Consequently, only 225 individual shrubs were sampled in the Mixed Brush type, which represents a reduction of 11 serviceberry (Amelanchier utahensis), 2 snowberry (Symphoricarpos oreophilus), 10 mountain mahogany (Cercocarpus montanus), and 2 pinyon pine. The following analyses reflect this change for data sets from all years.

Serviceberry exhibited the highest leader use (7 percent average for 101 living individuals), whereas pinyon pine had the lowest utilization (<1 percent average for 4 living individuals; Table 3-1). When the data for 1981 are compared to the 1980 data, there is a leader use increase for serviceberry (3 to 7 percent), sagebrush (Artemisia tridentata; 5 to 6 percent) and snowberry (1 to 5 percent), but a leader use decrease for mountain mahogany (21 to 5 percent) and pinyon pine (6 to <1 percent). These changes may be attributed to the removal of Transect 6 from the Mixed Brush type as well as variation in use by deer.

The results of a two-way ANOVA comparing leader use from 1978 to 1981 indicate significant interaction effects (year x transect) for both serviceberry and sagebrush (Table 3-2). Significant main effect differences between years were evident for serviceberry, whereas significant main effect differences between transects were exhibited by both serviceberry and sagebrush. Variations among years reflect apparent changes in overall utilization, while the differences among transects suggest variations in use patterns within the study area.

Table 3-1. Condition of Important Browse Species in Three Vegetation Types During April-May 1981 in the Vicinity of RBOSC Oil Shale Tract C-a

Vegetation Type [1/]	Species	Number of Plants Sampled	Avg. Util. (%)	Avg. Avail. (%)	Form Class (%) [2/]								Age Class (%)				Hedging Class (%)		
					1	2	3	4	5	6	7	8	Seedling	Young	Mature	Decadent	Light	Moderate	Severe
MB	Serviceberry	117	7	88	33	24	4	14	9	3	...	14	...	5	38	57	52	40	8
	Sagebrush	61	6	96	28	44	7	3	7	2	...	10	...	...	66	34	34	56	9
	Snowberry	39	5	72	21	10	...	38	8	3	10	10	...	13	36	51	77	19	3
	Mountain Mahogany	4	5	100	...	25	...	...	...	...	50	25	50	...	25	25	...	100	...
	Pinyon Pine	4	<1	100	100	...	...	...	...	...	...	...	...	...	100	...	100	...	...
PJ	Sagebrush	184	6	89	28	28	5	8	10	6	2	12	...	2	45	53	41	46	13
	Juniper	71	<1	34	13	...	...	63	...	...	8	15	1	1	55	42	98	2	...
	Pinyon Pine	67	3	53	19	4	...	60	6	...	7	3	4	1	88	6	88	12	...
	Bitterbrush	30	44	89	17	17	10	3	33	13	...	7	...	...	40	60	21	54	25
	Mountain Mahogany	28	36	86	4	39	21	4	4	29	...	...	...	...	46	54	7	43	50
	Serviceberry	14	3	82	...	29	29	7	14	7	...	14	...	...	50	50	8	50	42
	Snowberry	6	0	81	...	...	17	50	17	...	...	17	...	17	50	33	80	20	...
SB	Sagebrush	357	5	97	30	33	5	4	5	<1	...	23	...	...	41	58	44	50	7
	Serviceberry	10	15	87	20	10	...	40	10	10	...	10	...	20	50	30	67	22	11
	Snowberry	4	1	45	...	...	...	25	75	...	...	...	...	...	25	75	25	75	...
	Juniper	3	0	77	33	...	...	67	..	...	...	...	...	...	100	...	100	...	...
	Pinyon Pine	1	0	70	...	...	...	100	..	...	...	...	...	...	100	...	100	...	...

... indicates no individuals present in this category

1/ MB = Mixed Brush
PJ = Pinyon-Juniper
SB = Sagebrush

2/

Form Classes

1 All available, little or no hedging
2 All available, moderately hedged
3 All available, severely hedged
4 Partially available, little or no hedging
5 Partially available, moderately hedged
6 Partially available, severely hedged
7 Unavailable
8 Dead

Table 3-2. Summary of Two-way ANOVA Results Comparing Browse Leader Use from 1978 through 1981, Tract C-a[1/]

Vegetation Type	Species	Source of Variation: Year F	Year PR>F[2/]	Among Transects F	Among Transects PR>F[2/]	Year x Transect F	Year x Transect PR>F[2/]
MB	Serviceberry	4.28**	0.0056	6.12**	0.0001	1.62*	0.0343
	Sagebrush	0.14	0.9322	2.56**	0.0210	1.76*	0.0322
	Snowberry	1.29	0.2825	1.53	0.1625	0.89	0.6031
	Mountain Mahogany[3/]	0.75	0.5687	...	...	...	...
	Pinyon Pine[4/]	...	...	...	...	...	...
PJ	Sagebrush	17.09**	0.0001	2.43**	0.0028	3.56**	0.0001
	Pinyon Pine	5.70**	0.0011	3.73**	0.0001	1.57*	0.0441
	Juniper	1.31	0.2731	1.34	0.1916	1.25	0.2163
	Bitterbrush	29.69**	0.0001	4.68**	0.0001	1.30	0.2258
	Mountain Mahogany	17.21**	0.0001	16.15**	0.0001	5.97**	0.0001
	Snowberry	5.74**	0.0100	0.01	0.9181	0.05	0.9845
	Serviceberry	4.48**	0.0087	4.20**	0.0226	2.98**	0.0175
SB	Sagebrush	113.11**	0.0001	8.36**	0.0001	8.51**	0.0001
	Serviceberry	1.65	0.2110	0.95	0.4595	1.14	0.3852
	Snowberry[5/]	1.00	0.4262	...	...	...	...
	Pinyon Pine[6/]	...	...	...	...	...	...
	Juniper [6/]	...	...	...	...	...	...

* significant at $\alpha = 0.05$

** significant at $\alpha = 0.025$

1/ Complete analyses are presented in Appendix 3-1.1.

2/ PR>F represents the significance probability (α) associated with F.

3/ Species present on only one transect; therefore, source of variation occurs only among years.

4/ Insufficient data to produce ANOVA results.

5/ Species leader usage only in 1981; therefore, source variation occurs only among years.

6/ No leader use was noted.

Serviceberry utilization was significantly lower in 1980 than during 1978, 1979, or 1981 (Table 3-3). Leader usage of serviceberry among transects was varied; Transect 31 exhibited significantly lower leader use than Transects 34, 4 and 2 (Table 3-3). This lower leader use may be the result of a greater number of shrubs on Transect 31 than on Transect 34 with an age classification of "decadent". As defined by Cole (1963), the decadent category applies to individuals with more than 25 percent of the crown surface dead. Since more shrubs along Transect 31 are decadent, fewer leaders are produced each year, resulting in a decline of available forage for the deer. Furthermore, the differences between Transects 31 and 34 leader use may be due to the different species compositions. Transect 31 is composed solely of serviceberry, whereas serviceberry, sagebrush, and snowberry are found along Transect 34.

Utilization of sagebrush was not significantly different among years but was significantly different among transects. Sagebrush use on Transects 34 and 33 was significantly greater than on three of the remaining five Transects where it was encountered (Table 3-4).

The one-way ANOVA comparing leader usage for 1981 did not exhibit significant differences among Transects (Table 3-5).

The weighted average utilization for all individuals sampled within the Mixed Brush vegetation type was 6 percent during 1981 (Table 3-6). This represents a slight increase in overall usage from 1980 to 1981; however, usage is generally lower than for the 1976-1979 sampling periods. Based on Cole's (1963) classification levels for the use of vigorous, mature plants on winter range, all of the species sampled were judged to have "allowable" leader use rates for mild winter conditions. This classification is the same as that exhibited during the 1980 reporting period. The distribution of individual shrubs by form class has changed and, for example, the percentage of dead mountain mahogany plants has increased as a result of the transfer of Transect 6 from the Mixed Brush to the Pinyon-Juniper vegetation type. The majority of individuals remain in form classes 1, 2 and 4 (Table 3-1).

The range condition ratings, based on the percentage of individuals in the decadent age classification (Table 3-1) for species sampled in the Mixed Brush

Table 3-3. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Year and Transect) in Serviceberry Leader Use for 1978 to 1981 Within the Mixed Brush Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=393 MS=.0188971

GROUPING	MEAN	N	YEAR
A	0.091512	115	78
A			
A	0.082283	108	79
A			
A	0.077202	101	81
B	0.029995	105	80

ALPHA LEVEL=.05 DF=393 MS=.0188971

GROUPING			MEAN	N	TRANSECT
	A		0.156637	66	34
	A				
B	A		0.124566	27	4
B					
B	C		0.095146	47	2
B	C				
B	C	D	0.086453	17	33
B	C	D			
B	C	D	0.060533	48	1
	C	D			
	C	D	0.051023	47	32
	C	D			
	C	D	0.040988	24	3
	C	D			
	C	D	0.037793	66	35
		D			
		D	0.022215	87	31

Table 3-4. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Transect) in Sagebrush Leader Use for 1978 to 1981 Within the Mixed Brush Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=192 MS=.0354419

GROUPING	MEAN	N	TRANSECT
A	0.147090	27	34
A			
A	0.130255	36	33
A			
B A	0.063961	8	32
B A			
B A	0.054190	49	3
B			
B	0.025598	40	1
B			
B	0.020900	24	2
B			
B	0.014525	36	4

Table 3-5. Summary of One-way ANOVA Results Comparing Browse Leader Use for 1981, Tract C-a[1/]

Vegetation Type	Species	Source of Variation Among Transects	
		F	PR>F[2/]
MB	Serviceberry	1.38	0.2168
	Sagebrush	0.75	0.6121
	Snowberry	0.90	0.5261
	Mountain Mahogany[3/]	...	...
	Pinyon Pine[4/]	...	...
PJ	Sagebrush	9.15**	0.0001
	Pinyon Pine	2.12*	0.0313
	Juniper	30.76**	0.0001
	Bitterbrush	5.16**	0.0016
	Mountain Mahogany	3.42**	0.0247
	Snowberry[5/]	...	...
	Serviceberry	0.28	0.7612
SB	Sagebrush	11.12**	0.0001
	Serviceberry	1.58	0.3347
	Snowberry[4/]	...	...
	Pinyon Pine[5/]	...	...
	Juniper[5/]	...	...

* significant at $\alpha = 0.05$

** significant at $\alpha = 0.025$

1/ Complete analyses are presented in Appendix 3-1.1.

2/ PR>F represents the significance probability (α) associated with F.

3/ Species present only on one transect.

4/ Insufficient data to produce ANOVA results.

5/ No leader use was noted.

Table 3-6. Comparison of Weighted Average Utilization (%) in Three Vegetation Types During April 1976, April 1977, May 1978, May 1979, May 1980, and May 1981 on and Near Tract C-a[1/]

Vegetation Type	April 1976	April 1977	May 1978	May 1979	May 1980	May 1981
Mixed Brush	12	17	7	8	4	6
Pinyon-Juniper	27	24	31	15	10	9
Upland Sagebrush	[2/]	6	25	4	1	5

[1/] $\frac{\sum_{i=1}^{j} (\bar{x}_i n)}{\sum_{i=1}^{N} N_{ij}} \bar{W}x_{ij}$ Where $\bar{W}x$ is the weighted average utilization, N = 250 for 1976-1980, and 225, 400 and 375 for MB, PJ and SB, respectively during 1981

[2/] Data not available for 1976

vegetation type are "excellent" for pinyon pine and mountain mahogany, but "poor" for serviceberry, sagebrush, and snowberry according to the criteria established by Cole (1963). By contrast, ratings based on the percentage of severely hedged individuals indicate that all species sampled within the Mixed Brush vegetation type would receive an "excellent" condition rating. Because the same individual plants are sampled each year in the MDP studies, the condition rating based on hedging reflects the change in browsing pressure more accurately than does the rating based on age classification. The 1981 ratings based on hedging class indicate that the condition of serviceberry and mountain mahogany has improved from that exhibited during 1980, while the ratings for pinyon pine, sagebrush and snowberry have remained the same. These changes may reflect the removal of Transect 6 from the data set more than actual changes in browsing pressure.

b. Pinyon-Juniper - With the addition of five new transects and the transfer of Transect 6 to this vegetation type, a total of 400 individual shrubs was sampled during the 1981 reporting period. Bitterbrush (Purshia tridentata) and mountain mahogany exhibited the greatest leader utilization (44 and 36 percent, respectively) of the shrubs sampled. Twenty-eight living

individuals from each of these two species were sampled. Leader usage for snowberry was the lowest for this vegetation type (zero for the five living shrubs surveyed). From 1980 to 1981, leader use for bitterbrush (35 to 44 percent) and serviceberry (2 to 3 percent) increased but decreased for sagebrush (9 to 6 percent), pinyon pine (5 to 3 percent), mountain mahogany (41 to 36 percent), and snowberry (2 to 0 percent). Leader use for juniper from 1980 to 1981 remained similar at <1 percent.

The results of the two-way ANOVA for leader utilization from 1978 to 1981 indicate significant interaction effects (year x transect) for sagebrush, pinyon pine, mountain mahogany, and serviceberry (Table 3-2). All of the shrub species except juniper exhibited significant main effect year differences while all of the shrubs with the exception of juniper and snowberry showed significant main effect differences among transects. If significant main effect differences are not accompanied by a corresponding significant interaction effect (year x transect), it is expected that the main effect changes are not uniform.

The results of Duncan's multiple range test show that leader use for four species has declined significantly since 1978. Sagebrush utilization was significantly higher in 1978 than in 1979, 1980, or 1981 (Table 3-7). Variations in sagebrush leader use among transects for the four years result in four transect groupings (Table 3-7). Due to the complex nature of these groupings, trends in use pattern are not evident. Leader use for pinyon pine also was significantly higher in 1978 than in the other three years. Leader use of pine was significantly higher along Transect 17 than along any other transect within the vegetation type (Table 3-8). Utilization of pine on Transects 18 and 19 was similar to Transects 36, 6 and 43 but significantly higher than on the nine remaining transects. Bitterbrush leader use was significantly higher in 1978 than during the three remaining years. Usage was not significantly different from 1981 and 1980; however, use in 1981 was significantly higher than in 1979 (Table 3-9). Transects 42 and 11 experienced significantly greater bitterbrush use than on seven of the other eight transects on which bitterbrush is found (Table 3-9). Mountain mahogany exhibited significantly higher leader use in 1978 than in any other year. Leader use of for mahogany on Transect 6 was similar to two other transects but was significantly lower than the usage exhibited on Transects 17 and 12 (Table 3-10).

Table 3-7. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Year and Transect) in Sagebrush Leader Use for 1978 to 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=390 MS=.0504479

GROUPING	MEAN	N	YEAR
A	0.265570	91	78
B	0.124405	90	79
B			
C B	0.095124	92	80
C			
C	0.057890	157	81

ALPHA LEVEL=.05 DF=390 MS=.0504479

GROUPING	MEAN	N	TRANSECT
A	0.319551	15	12
A			
B A	0.233383	42	37
B A			
B A C	0.190499	49	19
B C			
B D C	0.145265	44	17
B D C			
B D C	0.139944	46	5
D C			
D C	0.110175	76	36
D C			
D C	0.077226	16	48
D C			
D C	0.066350	10	40
D			
D	0.062204	60	7
D			
D	0.050743	18	43
D			
D	0.048240	20	16
D			
D	0.038461	12	42
D			
D	0.005002	20	49
D			
D	0.000000	1	18
D			
D	0.000000	1	46

Table 3-8. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Year and Transect) in Pinyon Pine Leader Use for 1978 to 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=151 MS=.0366699

GROUPING	MEAN	N	YEAR
A	0.177519	47	78
B	0.084326	46	79
B			
B	0.051366	45	80
B			
B	0.030945	60	81

ALPHA LEVEL=.05 DF=151 MS=.0366699

GROUPING	MEAN	N	TRANSECT
A	0.558748	4	17
B	0.299441	8	18
B			
B	0.213743	22	19
B			
C B	0.163363	4	36
C B			
C B	0.127635	8	6
C B			
C B	0.100679	2	43
C			
C	0.072724	32	11
C			
C	0.054097	19	16
C			
C	0.032725	16	12
C			
C	0.026372	16	37
C			
C	0.021290	24	7
C			
C	0.019019	10	46
C			
C	0.007086	24	5
C			
C	0.001429	7	40
C			
C	0.000000	2	48

Table 3-9. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Year and Transect) in Bitterbrush Leader Use for 1978 to 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=86 MS=0.105741

GROUPING		MEAN	N	YEAR
	A	0.993019	31	78
	B	0.505010	28	81
	B			
C	B	0.385538	21	80
C				
C		0.263329	33	79

ALPHA LEVEL=.05 DF=86 MS=0.105741

GROUPING		MEAN	N	TRANSECT
	A	1.090266	2	42
	A			
	A	0.735568	40	11
	A			
B	A	0.609968	2	43
B				
B		0.536561	24	18
B				
B		0.474298	28	37
B				
B		0.333039	4	16
B				
B		0.261362	4	12
B				
B		0.100467	3	46
B				
B		0.016674	3	17
B				
B		0.000000	3	19

Table 3-10. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Year and Transect) in Mountain Mahogany Leader Use for 1978 to 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=90 MS=0.102575

GROUPING	MEAN	N	YEAR
A	0.938027	25	78
B	0.601785	27	79
C	0.385336	28	81
C			
C	0.384554	27	80

ALPHA LEVEL=.05 DF=90 MS=0.102575

GROUPING	MEAN	N	TRANSECT
A	0.834066	28	17
A			
A	0.720202	34	12
A			
B A	0.503502	4	16
B A			
B A	0.304693	1	48
B			
B	0.267796	40	6

Snowberry and serviceberry experienced greater browse utilization within the Pinyon-Juniper vegetation type in 1979 than in any other year sampled (Table 3-11). Leader use for snowberry was significantly higher in 1979 than in other years. Serviceberry utilization in 1979 was similar to that of 1978, but significantly higher than in 1980 or 1981 (Table 3-12), thereby leading to the partitioning of the transects into two distinct groups. Transect 12 exhibited significantly higher leader use than Transects 36 or 6.

Data indicate that utilization for most shrub species within the Pinyon-Juniper vegetation type has decreased since 1978. This decrease in leader usage may be a result of the variations in the mule deer herd size and changes in their winter range between 1978 and 1981. The 1978-79 winter was severe in terms of amount of snowfall and length of time deep snow was on the ground. As a result, a large portion of the deer herd in the area (and throughout the West) died of starvation and exposure (RBOSC 1981b). The normal 1979-80 winter and mild 1980-81 winter allowed the smaller herds to use an expanded area as winter range. Therefore, it is likely that browsing pressure since 1978 has been reduced and that this resulted in decreased leader use on RBOSC study areas.

The one-way ANOVA for 1981 leader utilization shows significant differences among transects for all species surveyed in the Pinyon-Juniper vegetation type except serviceberry (Table 3-5). Sagebrush leader usage was significantly higher on Transect 12 than on any other transect (Table 3-13). This seems to be due to 50 percent or greater leader use on three of the four plants surveyed. All five of the new transects (48, 43, 42, 49, and 46) surveyed experienced relatively low utilization (Tables 3-13 and 3-14).

Leader use for pinyon pine (Table 3-15) was significantly higher on Transects 6 and 43 than on six of twelve remaining transects where it was encountered. Browse utilization of pine on the new transects was varied. No individuals were surveyed on Transects 42 and 49, and very low utilization was recorded on Transects 48 and 46 (0 percent average for the two pines and 1.9% average for the 10 pines surveyed, respectively). Higher utilization was evident on Transect 43 (10 percent average for the two pinyon pines surveyed). Juniper leader use was significantly greater on Transect 49 than any of the other 14 transects (Table 3-16). As noted above, the transects established during 1981 experienced varied browse usage; Transects 43 and 48 exhibited relatively low

Table 3-11. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Year) in Snowberry Leader Use for 1978 to 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=13 MS=0.166473

GROUPING	MEAN	N	YEAR
A	0.897826	5	79
B	0.050254	6	78
B			
B	0.040118	5	80
B			
B	0.000000	5	81

Table 3-12. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Year and Transect) in Serviceberry Leader Use for 1978 to 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=38 MS=.0106154

GROUPING	MEAN	N	YEAR
A	0.170451	13	79
A			
B A	0.102181	12	78
B			
B	0.054855	13	80
B			
B	0.031796	12	81

ALPHA LEVEL=.05 DF=38 MS=.0106154

GROUPING	MEAN	N	TRANSECT
A	0.232798	4	12
B	0.090600	6	36
B			
B	0.076548	40	6

Table 3-13. Results of Duncan's Multiple Range Tests for Significant Transect Differences in Sagebrush Leader Use for 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=143 MS=.0117364

GROUPING	MEAN	N	TRANSECT
A	0.603534	3	12
B	0.192439	11	17
B			
C B	0.154697	10	37
C			
C D	0.077226	16	48
D			
D	0.050743	18	43
D			
D	0.038461	12	42
D			
D	0.027342	11	5
D			
D	0.026468	19	36
D			
D	0.007146	14	7
D			
D	0.005002	20	49
D			
D	0.000000	5	16
D			
D	0.000000	12	19
D			
D	0.000000	5	40
D			
D	0.000000	1	46

Table 3-14. Comparison of Sagebrush Utilization Along Transects Established During 1981, Tract C-a and Vicinity.

Transect	Number of Sagebrush Surveyed	Highest Percentage Sagebrush Leader Use[1/]	Lowest Percentage Sagebrush Leader Use[1/]
48	16	50 (1)	0 (11)
43	18	40 (1)	0 (13)
42	12	40 (1)	0 (10)
49	20	5 (2)	0 (18)
46	1	0 (1)	0 (1)

[1/] Numbers in parentheses represent the number of individuals falling within respective use classes.

Table 3-15. Results of Duncan's Multiple Range Tests for Significant Differences in Pinyon Pine Leader Use Among Transects for 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=46 MS=.0025662

GROUPING	MEAN	N	TRANSECT
A	0.105679	2	6
A			
A	0.100679	2	43
A			
B A	0.100167	1	36
B A			
B A	0.080134	5	19
B A			
B A	0.064095	8	11
B A			
B A	0.033368	6	7
B A			
B A	0.019019	10	46
B A			
B A	0.005000	4	16
B			
B	0.003333	6	5
B			
B	0.000000	5	12
B			
B	0.000000	1	17
B			
B	0.000000	4	37
B			
B	0.000000	4	40
B			
B	0.000000	2	48

Table 3-16. Results of Duncan's Multiple Range Tests for Significant Transect Differences in Juniper Leader Use for 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=39 MS=5.7E-06

GROUPING		MEAN	N	TRANSECT
	A	0.050021	1	49
	B	0.002857	7	46
	B			
C	B	0.002000	5	42
C	B			
C	B	0.000000	3	5
C	B			
C	B	0.000000	2	7
C	B			
C	B	0.000000	5	11
C	B			
C	B	0.000000	1	12
C	B			
C	B	0.000000	3	15
C	B			
C	B	0.000000	2	17
C	B			
C	B	0.000000	4	19
C	B			
C	B	0.000000	3	36
C	B			
C	B	0.000000	3	37
C				
C		0.000000	12	40
C				
C		0.000000	1	43
C				
C		0.000000	2	48

browse utilization, while Transects 46, 42, and 49 experienced high utilization. The utilization of bitterbrush was significantly higher on Transects 42 and 11 than on six of seven remaining transects (Table 3-17). Browse utilization on the new transects (42, 43, and 46) was similar to that on most of the original transects (Table 3-17).

Results from the one-way ANOVA indicate a significant difference for mountain mahogany among transects sampled in 1981 (Table 3-15). When the data were analyzed with Transect 6 excluded, however, no significant differences in the one-way ANOVA (F value of 0.33 and PR>F of 0.8057) were found. Therefore, Transect 6 seems very influential in the ANOVA.

The weighted average utilization based on all individuals sampled in the Pinyon-juniper vegetation type was 9 percent (Table 3-6). This represents a slight reduction in utilization from the 10 percent recorded during 1980. Reduced use may be a result of the mild 1980-81 winter conditions, which allowed for increased use of other vegetation types. It also should be noted that the increased sample size during 1981 has influenced these data. Nevertheless, 1981 use values would be deemed "acceptable" for average winters in the case of bitterbrush and mountain mahogany. All other species sampled exhibited "acceptable" leader use for mild winter conditions.

With increased sample size, the distribution of individuals by form class changed slightly. The percentage of dead plants (form class 8) increased for sagebrush, juniper, pinyon pine, and serviceberry, remained the same for mountain mahogany, and decreased for snowberry and bitterbrush. Distribution among the other form classes was variable; however, form classes 1, 2, and 4 are the most prominent (Table 3-1).

Range condition ratings based on age distribution were "poor" for sagebrush, juniper, mountain mahogany, serviceberry, and snowberry. Pinyon pine condition was judged to be "excellent", while bitterbrush was judged "very poor". Mountain mahogany and serviceberry would have "poor" condition ratings based on the percentage of severely hedged shrubs (50 and 42 percent, respectively; Table 3-1). The remaining species received more favorable ratings based on the hedging classification rather than on age distribution. Juniper, pinyon pine, and snowberry had "excellent" ratings; sagebrush exhibited "good" condition;

Table 3-17. Results of Duncan's Multiple Range Tests for Significant Transect Differences in Bitterbrush Leader Use for 1981 Within the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=19 MS=.0786331

GROUPING	MEAN	N	TRANSECT
A	1.090266	2	42
A			
A	0.814427	10	11
A			
A	0.609968	2	43
B			
B	0.284770	7	37
B			
B	0.150568	1	12
B			
B	0.100467	3	46
B			
B	0.100167	1	16
B			
B	0.050021	1	17
B			
B	0.000000	1	19

and bitterbrush was judged to have a "fair" condition rating. For most species, ratings based on the hedged classification show a marked improvement over the ratings made during 1980. This may be due in part to decreased grazing pressure, but the majority of the change probably results from the addition of the new transects. Shrubs in the Pinyon-Juniper stands on and adjacent to the RBOSC off-tract property to the north of Tract C-a (see Figure 3-1 for location of new transects) are not as heavily utilized as are similar habitats on Tract C-a. An example of this is shown by the Duncan's Multiple Range Test results for sagebrush (Table 3-7 and 3-13). All five of the new transects (48, 43, 42, 49, and 46) exhibit relatively light grazing, as evidenced by their locations in the bottom one-half of these tables. This observation will need to be confirmed in upcoming years.

c. Sagebrush - Fifteen transects (375 individual shrubs) were sampled during 1981. In comparison to data from 1980 studies, 122 sagebrush and three junipers were added to the data set in 1981. Serviceberry was browsed most heavily; the nine living shrubs of this species averaged 15 percent leader use. The 275 living sagebrush individuals averaged 5 percent leader use. No leader use was recorded for juniper or pinyon pine, and snowberry recorded only one percent use for four living individuals. From 1980 to 1981, leader use increased for sagebrush (1 to 5 percent), serviceberry (1 to 15 percent), and snowberry (0 to 1 percent), while leader use for pinyon pine remained unchanged (0 percent for both years). A historical trend analysis of juniper utilization cannot be made since the three shrubs surveyed occur on the new transects established in 1981.

A statistical comparison of utilization (Table 3-2) between years and among transects (main effects), as well as a comparison of utilization for years x transects (interaction effect), indicated significant differences for sagebrush. Leader use for sagebrush was significantly higher in 1978 than in any other year (Table 3-18). Variations in sagebrush leader use among transects for 1978 to 1981 result in five transect groupings (Table 3-18). However, due to the complex nature of these groupings, trends in use pattern are not evident.

Table 3-18. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Year and Transect) in Sagebrush Leader Use for 1978 to 1981 Within the Sagebrush Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=771 MS=.0292096

GROUPING	MEAN	N	YEAR
A	0.298972	186	78
B	0.056100	275	81
B			
C B	0.039711	182	79
C			
C	0.011391	173	80

ALPHA LEVEL=.05 DF=771 MS=.0292096

GROUPING	MEAN	N	TRANSECT
A	0.193043	58	8
A			
A	0.184723	59	10
A			
A	0.176651	90	30
A			
B A	0.164634	80	38
B			
B C	0.117654	70	15
C			
D C	0.097273	74	20
D C			
D C E	0.077966	19	47
D C E			
D C E	0.060490	21	50
D C E			
D C E	0.054860	66	22
D C E			
D C E	0.052258	20	41
D E			
D E	0.048153	79	39
E			
E	0.024158	68	14
E			
E	0.015305	21	44
E			
E	0.012010	25	45
E			
E	0.002274	66	28

The one-way ANOVA of leader usage in 1981 among transects (Table 3-5) exhibited a significant difference only for sagebrush. Transect 8 experienced significantly greater sagebrush use than any other transect encountered in this vegetation type (Table 3-19). All five of the new transects (47, 50, 41, 44, and 45) experienced significantly lower leader use than Transects 8, 38, and 15 (Table 3-19).

Weighted average utilization for all shrubs sampled increased from one percent for 1980 to five percent for the 1981 reporting period (Table 3-6). This increase results primarily from the increased leader use for sagebrush and serviceberry. These use values are well within the "allowable" range which Cole (1963) suggests for mild winters. The reasons for increased utilization when little or no change in the size of the deer herd was noted are not entirely clear. At first, the increased utilization was thought to be a result of heavier sagebrush and serviceberry leader use on the five new transects than on the original ten transects. However, this supposition cannot be supported after reviewing the Duncan's Multiple Range Test results for sagebrush (Table 3-19). All five of the new transects (47, 50, 41, 44, and 45) are in the lowest Duncan's grouping. Furthermore, no utilization for serviceberry was noted on any of the new transects. Sampling in upcoming years may clarify these results.

Increased sample size did not influence form class distribution to any large degree. The majority of the individuals in the sample continue to be categorized in form classes 1 and 2. There was a 3 percent increase in dead (form class 8) sagebrush plants associated with an increase of 52 percent in the number of sagebrush plants sampled. The corresponding increase of dead sagebrush associated with the new transects within the Pinyon-Juniper type was 12 percent.

The range condition rating for sagebrush and snowberry was "very poor" based on the percentage of plants in the decadent age class. The corresponding rating for servicberry was "fair", while both juniper and pinyon pine exhibited "excellent" range condition ratings. These values are similar to those obtained during the 1980 reporting period. However, based on hedging class distribution, sagebrush, snowberry, juniper, and pinyon pine had "excellent"

Table 3-19. Results of Duncan's Multiple Range Tests for Significant Transect Differences in Sagebrush Leader Use for 1981 Within the Sagebrush Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=260 MS=.0103236

GROUPING	MEAN	N	TRANSECT
A	0.318453	14	8
B	0.178960	20	38
C	0.085359	15	15
C			
D C	0.077966	19	47
D C			
D C	0.060490	21	50
D C			
D C	0.052258	20	41
D C			
D C	0.038595	15	14
D C			
D C	0.031655	13	10
D C			
D C	0.022754	22	30
D C			
D C	0.015305	21	44
D C			
D C	0.012010	25	45
D C			
D C	0.006253	16	22
D C			
D C	0.002779	18	20
D			
D	0.002501	20	39
D			
D	0.000000	16	28

range condition ratings. Serviceberry had an "excellent" rating in 1980 but was rated as "good" during the 1981 reporting period.

d. Mixed Brush/Pinyon-Juniper/Sagebrush - It is interesting to note that when comparing all browse species sampled in 1981, bitterbrush was the most heavily browsed shrub species, with significantly greater leader usage than any other shrub (Table 3-20). Part of this high leader use is due to the low number of bitterbrush surveyed as well as the extremely high leader usage on Transect 11 (an average of 71% for the 10 bitterbrush surveyed). Transect 11 is on a south-facing slope near RBOSC activities within Block 5 of the mule deer study area (see Section 3.2C of this report). Block 5 has consistently had some of the highest mule deer densities, and since Transect 11 is on a south-facing slope, bitterbrush would be available throughout most of the year.

Table 3-20. Results of Duncan's Multiple Range Tests for Significant Differences in Leader Use for All Species Sampled in 1981, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=821 MS=.0292747

GROUPING	MEAN	N	SPECIES
A	0.505010	28	PUR TRI
B	0.373774	29	CER MON
C	0.078667	122	AME UTA
C			
C	0.057139	487	ART TRI
C			
D C	0.050892	40	SYM ORE
D C			
D C	0.028719	65	PIN EDU
D			
D	0.001404	57	JUN OST

C. Phytosociology Studies

1. Objectives

The objective of the phytosociological studies is to monitor the species composition and coverage in the major vegetation types expected to be affected by Tract C-a development. These studies provide quantitative data which complement information on the distribution of major habitat types and provide continuity with similar data collected during the baseline period.

2. Methods

Phytosociological studies are conducted in the Pinyon-Juniper and the Sagebrush vegetation types on a control site south of Tract C-a (Area 6), in a treatment site just east of RBOSC's off-tract land (Area 7), and on a second treatment site on Airplane Ridge (Area 5; Figure 3-1). These sites correspond to the sampling locations for the small mammal and avifauna studies. The "treatment" defined as part of the monitoring program includes potential effects of air pollutant emissions and other associated impacts. As development progresses, the treatment sites will be moved as necessary.

Phytosociological sampling is conducted every three years in a specific vegetation type on a rotation basis. During the initial sampling period in each vegetation type, the density and cover of woody species, and cover of herbaceous species are determined. Thereafter, only herbaceous cover is measured. Sampling in the Pinyon-Juniper type was conducted in Areas 5 and 6 in June 1979 and was conducted in the Sagebrush type in the same areas during June 1980. With the addition of Area 7 to the monitoring program, sampling of both the Pinyon-Juniper and Sagebrush types in that area occurred during 1981. The cycle will continue with sampling of the Pinyon-Juniper type in all three areas in 1982. The methods used to collect these data were presented in MDP Monitoring Report 5 (RBOSC 1980).

With only one sampling year's data in each of the three areas, herbaceous cover data for Sagebrush and Pinyon-Juniper vegetation types are arcsine transformed and analyzed by the following one-way ANOVA to compare control and treatment sites:

Source of Variation	Degrees of Freedom	F-Test
A. Transects a = 5	a-1	A/B
B. Error (n = 5)	a(n-1)	
	Total an-1	

This one-way ANOVA is used to determine the differences in herbaceous cover among the three locations. If the effect is significant, then multiple range tests are performed.

A second one-way ANOVA for transects within Area 7 is used to determine if there are any significant differences between transects for each vegetation type in Treatment Area 7:

Source of Variation	Degrees of Freedom	F-Test
A. Transects a = 5	a-1	A/B
B. Error (n = 5)	a(n-1)	
	Total an-1	

Because the woody species data are collected only once, these data are not amenable to ANOVA among years; however, they will serve as "baseline" information for the control and treatment sampling sites. If development-related impacts are detected by photoplot or vegetation distribution monitoring programs, then additional sampling programs for woody species will be initiated.

3. Results and Discussion

The pinyon-juniper and sagebrush transects in Treatment Area 7 were sampled June 3-12, 1981. Photoplots for all transects were established during the same period. The ranges and averages for coverage and/or density of species encountered along the five transects in each of these two vegetation types are reported herein and the raw data are presented in Appendix 3-1.2.

a. Pinyon-Juniper - The average coverage of trees and shrubs in Area 7 was 44.2 percent (Table 3-21). Pinyon pine (Pinus edulis) and juniper (Juniperus osteosperma) accounted for 90 percent of this coverage while sagebrush (Artemisia tridentata) and bitterbrush (Purshia tridentata) made up the remaining woody species coverage. Coverage of woody species within the Pinyon-juniper type was higher in Areas 5 and 6 than on transects within Area 7. Total coverage for woody species in Area 5 was 58.0 percent, whereas coverage was 51.6 percent for the woody species of Area 6. As in Area 7, pinyon pine and juniper were responsible for the majority of this coverage (87 and 94 percent of the total for Areas 5 and 6, respectively). These data were presented in the MDP Monitoring Report 5 (RBOSC 1980).

Table 3-21. Density and Coverage of Shrub and Tree Species Encountered in the Pinyon-Juniper Vegetation Type for Treatment Area 7 During 1981, Tract C-a

Species	Average Density (stems/ha)	Range (stems/ha)	Average Cover (%)	Range (%)
Shrubs				
Artemisia tridentata	1,100	150-2,400	2.8	0-6.2
Chrysothamnus nauseosus	7	0-33	...	...
Purshia tridentata	450	0-1,250	1.5	0-4.0
Subtotal	1,557		4.3	
Trees				
Juniperus osteosperma	243	167-350	15.6	10.2-21.6
Pinus edulis	153	83-233	24.3	16.1-37.7
Subtotal	396		39.9	
Total	1,953		44.2	

... indicates no individual present in this category

Sagebrush in Area 7 had the highest density of any woody species encountered in this vegetation type (1,100 stems per hectare; Table 3-21), while rubber rabbit-

brush (Chrysothamnus nauseosus) had the lowest shrub density (7 stems per hectare). Pinyon pine exhibited the lowest tree density (153 stems per hectare; Table 3-21). A comparison of density values between the three locations reveals that Area 5 exhibited the highest total woody species density (5,848 stems per hectare), while Area 7 experienced the lowest (1,953 stems per hectare; Table 3-22). Approximately 48 percent of the density in Area 5 can be attributed to sagebrush (28 percent) and pine (20 percent). Area 6 had a total woody species density of 3,272 stems per hectare, primarily composed of sagebrush, pine, and juniper (33, 24, and 20 percent of the total, respectively; RBOSC 1980). The differences between these three areas are a function of the community structure in each area and are not indicative of Tract C-a activities. As mentioned previously, these data represent "baseline" conditions for each area, thereby allowing for the tracking of any Tract C-a development-related changes that may occur in the future.

Table 3-22. Density of Shrubs and Trees Encountered in the Pinyon-Juniper Vegetation Type for Control Area 6 and Treatment Areas 5 and 7, Tract C-a and Vicinity.

Location	Total Shrub Density (stems/ha)	Total Tree Density (stems/ha)	Total Woody Species Density (stems/ha)
Control Area 6[1/]	1,852	1,420	3,272
Treatment Area 5[1/]	4,129	1,719	5,848
Treatment Area 7	1,557	396	1,953

[1/] Data are presented in their entirety in MDP Monitoring Report No. 5 (RBOSC 1980).

Grass species averaged 12.3 percent coverage for Area 7 (Table 3-23). Poa (bluegrass) species (6.6 percent average coverage) and the Agropyron (wheatgrass) species (3.9 percent average coverage) accounted for 85 percent of the total grass coverage. The one-way ANOVA results comparing grass coverage among the five transects does not exhibit any significant differences (Table 3-24).

Table 3-23. Percent Cover of Grass and Forb Species Encountered on Transects in the Pinyon-Juniper Vegetation Type for Treatment Area 7 during 1981, Tract C-a

Species	Average Cover (%)	Range (%)
Grasses		
Agropyron species	3.15	0 -5.60
A. trachycaulum	0.74	0 -3.70
Bromus tectorum	0.01	0 -0.05
Carex species	0.05	0 -0.20
Hordeum jubatum	0.05	0 -0.25
Koeleria cristata	0.15	0 -0.55
Oryzopsis hymenoides	1.48	0.55-2.35
Poa species	2.88	0 -5.20
P. canbyi	1.71	0.65-2.45
P. fendleriana	1.98	0.45-5.10
Stipa comata	0.10	0 -0.50
Total Grass Coverage	12.30	
Forbs		
Antennaria microphylla	0.08	0 -0.40
Arabis divaricarpa	0.02	0 -0.10
Arenaria fendleri	0.02	0 -0.05
Astragalus diversifolius	0.07	0 -0.15
A. purshii	0.06	0 -0.15
A. spatulatus	0.11	0 -0.55
Chamaesyce fendleri	0.01	0 -0.05
Cryptantha sericea	0.79	0.40-1.55
Eriogonum species	0.01	0 -0.05
Euphorbia species	0.12	0 -0.60
Haplopappus acaulis	0.03	0 -0.15
H. nuttalii	0.30	0 -0.60
Heterotheca villosa	0.05	0 -0.25
Ipomopsis aggregata	0.03	0 -0.10
I. congesta	0.06	0 -0.30
Lappula redowskii	0.01	0 -0.05
Leptodactylon pungens	0.07	0 -0.35
Opuntia polyacantha	0.01	0 -0.05
Phlox hoodii	1.21	0.40-1.85
Physaria floribunda	0.19	0 -0.35
Senecio multilobatus	0.23	0.15-0.35
Sisymbrium linifolium	0.01	0 -0.05
Townsendia incana	0.05	0 -0.20
Trifolium gymnocarpon	0.04	0 -0.20
Unknown composite	0.04	0 -0.10
Unknown forb species	0.10	0 -0.15
Total Forb Coverage	3.72	
Total Herbaceous Coverage	16.02	

Table 3-24. Summary of One-Way ANOVA Results Comparing Grass and Forb Coverage on Five Transects in the Pinyon-Juniper Vegetation Type for Treatment Area 7 During 1981, Tract C-a[1/]

Growth Form	Source of Variation (Transects) F	PR>F[2/]
Grasses	0.42	0.7954
Forbs	0.19	0.9441

[1/] Complete analyses are presented in Appendix 3-1.3.

[2/] PR>F represents the significance probability (α) associated with F.

Grass coverage on Areas 5 and 6 (8.8 and 7.3 percent, respectively) was lower than on Area 7. The most prominent grass species in Area 5 was Indian ricegrass (Oryzopsis hymenoides), with an average coverage of 4.6 percent, whereas bluegrass species (3.2 percent average coverage) were the dominant grasses in Area 6 (RBOSC 1980). The statistical comparison of grass coverage among the three locations showed no significant differences (Table 3-25).

Table 3-25. Summary of One-Way ANOVA Results Comparing Grass and Forb Coverage in the Pinyon-Juniper Vegetation Type for Control Area 6 and Treatment Areas 5 and 7, Tract C-a[1/]

Growth Form	Source of Variation (Location) F	PR>F[2/]
Grasses	1.14	0.3268
Forbs	0.86	0.4262

[1/] Complete analyses are presented in Appendix 3-1.3.

[2/] PR>F represents the significance probability (α) associated with F.

Total forb coverage for Area 7 averaged 3.7 percent (Table 3-23), with Hood's phlox (Phlox hoodii) and Cryptantha sericea accounting for over one-half (54 percent) of this coverage. Subordinate forb species included goldenweed (Haplopappus nuttallii), lobeleaf groundsel (Senecio multilobatus), and twinpod (Physaria floribunda). The statistical comparison between transects in Area 7 does not show any significant differences (Table 3-24).

A comparison of total forb coverage among the three locations shows that cover was higher in Areas 5 (6.0 percent) and 6 (6.4 percent) than in Area 7. However, the one-way ANOVA comparing forb coverage between these three areas does not exhibit any significant differences (Table 3-25). The predominant forb species in Area 5 were arrowleaf balsamroot (Balsamorhiza sagittata), Lithospermum ruderale, and Cryptantha sericea (RBOSC 1980). Of the 30 species identified in Area 6, no species attained an average cover of one percent, and there were no clear dominants.

b. Sagebrush - Average cover for shrubs and trees within Area 7 was 22.3 percent (Table 3-26). Sagebrush accounted for 92 percent of this total. The remaining eight percent coverage was composed of Douglas rabbitbrush (Chrysothamnus viscidiflorus), rubber rabbitbrush, and juniper. Coverage was higher for woody species in Areas 5 and 6 than in Area 7. Total woody species coverage in Area 5 was 31.6 percent whereas total coverage in Area 6 was 86 percent (RBOSC 1981). Sagebrush was the dominant in both areas; however, subordinant shrubs, including rubber rabbitbrush, snowberry (Symphoricarpos oreophilus) and Utah serviceberry (Amelanchier utahensis), were more prevalent in Area 5 than Area 6. As previously mentioned, these differences between locations are due to community structure and are not a result of Tract C-a activities.

Sagebrush exhibited the highest density (9,573 stems per hectare) of any woody species sampled in Area 7 (Table 3-26). On the other hand, Utah serviceberry exhibited the lowest shrub density (3 stems per hectare); pinyon pine had the lowest tree density, averaging 20 stems per hectare. The total woody species density (11,287 stems per hectare) was greater than the total for Area 6 (9,727 stems per hectare) but considerably less than what was surveyed on Area 5 (14,891 stems per hectare; Table 3-27).

Table 3-26. Density and Coverage of Shrub and Tree Species Encountered in the Sagebrush Vegetation Type for Treatment Area 7 During 1981, Tract C-a

Species	Average Density (stems/ha)	Range (stems/ha)	Average Cover (%)	Range (%)
Shrubs				
Amelanchier utahensis	3	0-17	...	...
Artemisia tridentata	9,573	6,950-11,767	20.5	16.1-27.8
Ceratoides lanata	47	0-233	...	...
Chrysothamnus nauseosus	237	0-750	0.4	0-1.2
C. viscidiflorus	1,280	0-4,083	1.4	0-4.9
Tetradymia canescens	10	0-33	...	...
Subtotal	11,150		22.3	
Trees				
Juniperus osteosperma	117	50-200	0.04	0-0.2
Pinus edulis	20	0-50	...	...
Subtotal	137		0.04	
Total	11,287		22.34	

... indicates no individuals present in this category

Table 3-27. Density of Shrub and Tree Species Encountered in the Sagebrush Vegetation Type for Control Area 6 and Treatment Areas 5 and 7, Tract C-a

Location	Total Shrub Density (stems/ha)	Total Tree Density (stems/ha)	Total Woody Species Density (stems/ha)
Control Area 6[1/]	9,687	40	9,727
Treatment Area 5[1/]	14,828	63	14,891
Treatment Area 7	11,150	137	11,287

[1/] Data are presented in their entirety in MDP Monitoring Report 5 (RBOSC 1981).

Total grass coverage for Area 7 was 21.7 percent with Poa species, the predominant grass species, constituting 48 percent of the total coverage (Table 3-28). Needle-and-thread (Stipa comata) and Agropyron species represented most of the remaining coverage. The one-way ANOVA comparing grass coverage between the five transects of Area 7 did not exhibit any significant differences (Table 3-29).

A comparison of grass coverage between the three areas shows that total grass coverage on Area 7 (21.7 percent) is comparable to the other two locations. Grass coverage on Area 5 was slightly lower (19.2 percent), while coverage on Area 6 was slightly higher (24.4 percent; RBOSC 1980). Poa species were the dominant grasses at all three locations. The statistical comparison of grass coverage between the three areas showed no significant differences (Table 3-30).

Total forb coverage averaged 8.4 percent for the five sagebrush transects in Area 7. (Table 3-28). The dominant forb species, which accounted for 38 percent of the total coverage, was Hood's phlox. Subordinate forb species included scarlet globemallow (Sphaeralcea coccinea) and Cryptantha sericea. The statistical analysis comparing forb coverage between transects in Area 7 did not exhibit significant differences (Table 3-29).

Forb coverage in Areas 5 and 6 was higher than the total forb coverage of Area 7. Forb coverage in Area 5 was 13.2 percent, in contrast to Area 6, where forb coverage was 20.4 percent (RBOSC 1981b). There were also slight differences in species richness and dominance between the three areas. The number of forb species encountered in Control Area 6 exceeded that in either treatment areas (38, 33, and 31 for Areas 6, 7, and 5, respectively). The predominant species in Area 6 were northern sweetvetch (Hedysarum boreale) and silvery lupine (Lupinus argenteus), while Hood's phlox was the predominant forb species in Area 5. The one-way ANOVA results comparing forb coverage between locations approach significance at the 0.05 level (Table 3-30).

Table 3-28. Percent Cover of Grass and Forb Species Encountered on Transects in the Sagebrush Vegetation Type for Treatment Area 7 during 1981, Tract C-a

Species	Average Cover (%)	Range (%)
Grasses		
Agropyron species	3.60	2.20-5.85
Carex species	1.05	0 -4.10
Hordeum jubatum	0.22	0 -0.70
Koeleria cristata	1.29	0.75-1.85
Oryzopsis hymenoides	1.27	0.05-2.80
Poa species	2.25	0-4.60
P. canbyi	5.90	3.05-7.50
P. fendleriana	2.18	1.00-3.85
Stipa comata	3.90	2.20-6.30
Total Grass Coverage	21.66	
Forbs		
Agoseris species	0.05	0 -0.15
Arenaria fendleri	0.01	0 -0.05
Astragalus diversifolius	0.10	0 -0.20
A. purshii	0.35	0.20-0.55
A. spatulatus	0.05	0 -0.25
Castilleja chromosa	0.03	0 -0.05
Crepis occidentalis	0.17	0 -0.15
Cryptantha sericea	0.74	0.45-1.70
Delphinium nelsonii	0.02	0 -0.10
Eriogonum engelmannii	0.24	0 -1.20
E. ovalifolium	0.13	0 -0.65
Haplopappus acaulis	0.03	0 -0.15
H. nuttalii	0.33	0 -1.45
Hedysarum boreale	0.46	0 -1.65
Heterotheca villosa	0.01	0.05-1.65
Ipomopsis aggregata	0.01	0 -0.05
I. congesta	0.04	0 -0.20
Linum lewisii	0.20	0 -0.95
Lomatium species	0.03	0 -0.15
Opuntia polyacantha	0.18	0 -0.70
Penstemon fremontii	0.06	0 -0.25
Phlox hoodii	3.15	1.70-5.15
P. longifolia	0.03	0 -0.15
Physaria floribunda	0.05	0 -0.20
Senecio species	0.01	0 -0.05
S. multilobatus	0.09	0 -0.25
Sisymbrium linifolium	0.12	0 -0.30
Sphaeralcea coccinea	0.77	0 -1.75
Townsendia incana	0.08	0 -0.30
Trifolium gymnocarpon	0.11	0 -0.50
Unknown composite	0.53	0 -1.05
Unknown forb species	0.17	0 -0.55
Zygadenus venenosus	0.04	0 -0.15
Total Forb Coverage	8.39	
Total Herbaceous Coverage	30.05	

Table 3-29. Summary of One-Way ANOVA Results Comparing Grass and Forb Coverage in the Sagebrush Vegetation Type for Treatment Area 7 During 1981, Tract C-a[1/]

Growth Form	Source of Variation (Transects)	
	F	PR>F[2/]
Grasses	0.09	0.9838
Forbs	0.17	0.9531

[1/] Complete analyses are presented in Appendix 3-1.3.

[2/] PR>F represents the significance probability (α) associated with F.

Table 3-30. Summary of One-Way ANOVA Results Comparing Grass and Forb Coverage in the Sagebrush Vegetation Type for Control Area 6 and Treatment Areas 5 and 7, Tract C-a[1/]

Growth Form	Source of Variation (Location)	
	F	PR>F[2/]
Grasses	2.93	0.0578
Forbs	2.88	0.0575

[1/] Complete analyses are presented in Appendix 3-1.3.

[2/] PR>F represents the significance probability (α) associated with F.

D. Range Productivity and Utilization

1. Objectives

Tract C-a MDP activities may affect range conditions on and near the tract by altering the use patterns of deer, cattle, and feral horse populations, thus changing the grazing pressure. The range studies are designed to provide information which can be used to compare range productivity and utilization before and during modular development. Because activities associated with tract development are confined primarily to the mine process area, impacts on range conditions are projected to be localized. Therefore, range studies focus on areas of Tract C-a and vicinity that are adjacent to MDP activities, and that were used for grazing previous to MDP activities.

2. Methods

The methods followed for collection of range data were described in MDP Monitoring Reports 1, 2, 3, 4, and 5 (RBOSC 1978a, 1978b, 1979a, 1979b, 1980). During the current reporting period, broom snakeweed (Gutierrezia sarothrae), a shrub species previously included in the forb analyses, was dropped. For production purposes, only the grass and forb species were analyzed.

The range productivity data are analyzed by using the following two-way ANOVA to compare pre-development conditions with those during development.

Source of Variation	Degrees of Freedom	F-Test
A. Year a = 3	a-1	A/D
B. Protected vs. Unprotected Plots b = 2	b-1	B/D
C. Phase x Plots	(a-1)(b-1)	C/D
D. Error	ab(n-1)	
	Total abn-1	

In order to test for differences which may have been masked by combining plot types in the ANOVA, production data for each vegetation type also were analyzed using a one-way ANOVA in order to ascertain differences among transects for 1981, as well as among vegetation types for 1978, 1979, 1980, and 1981.

3. Results and Discussion

During the 1981 sampling year, five new Pinyon-Juniper and five new sagebrush transects were added. These new transects are located around the RBOSC off-tract land just north of Tract C-a. These 10 new transects along with the other 30 transects, were sampled from August 26 to September 10, 1981 (Figure 3-1). Production data are summarized in Table 3-31 and are presented in their entirety in Appendix 3-1.4.

a. Mixed Brush - Average forage production for caged plots was 440.8 kg/ha, as compared to 343.4 kg/ha for the uncaged plots (Table 3-31). Species composition was comparable between the caged and uncaged plots; total grass production accounted for 44 and 41 percent, respectively, and total forb production represented for 56 and 59 percent, respectively. Dominant grasses, accounting for 91 percent of the production in caged and 96 percent in uncaged plots, consisted of wheatgrass (Agropyron) species, bluegrass (Poa) species, and Indian ricegrass (Oryzopsis hymenoides). Hood's phlox (Phlox hoodii), bastard toadflax (Comandra umbellata), stemless goldenweed (Haplopappus acaulis), sulfur eriogonum (Eriogonum umbellatum), and "unknown" forbs constituted 60 and 63 percent of the production for the caged and uncaged plots, respectively.

Analysis of the 1981 data from the Mixed Brush habitat type by a one-way ANOVA indicated no significant differences in grass and forb coverage for caged or uncaged plots (Table 3-32).

Caged plot production in 1981 (441 kg/ha) far exceeded the production recorded in 1978, 1979, or 1980 (210, 244, and 291 kg/ha, respectively; Table 3-33). Likewise, production was higher for the uncaged plots in 1981 (343 kg/ha) than in previous years (146, 173, and 202 kg/ha for 1978, 1979, and 1980, respectively. With few exceptions, the dominant grass and forb species encountered in 1981 were the same as those reported in other years.

Table 3-31. Range Production (standing crop, dry weight, kg/ha) of Species Encountered in Caged and Uncaged Plots Within Three Vegetation Types During 1981, Tract C-a

Species	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Caged	Uncaged	Caged	Uncaged	Caged	Uncaged
Plots (N)[1/]	(45)	(45)	(79)	(81)	(73)	(77)
Grasses						
Agropyron species	105.3	75.4	19.1	13.5	89.5	42.7
Bromus tectorum			1.8	0.02	10.4	8.3
Carex species		0.3	0.1	0.01	2.5	2.6
Koeleria cristata	16.6	2.4	0.7	0.2	9.4	6.4
Oryzopsis hymenoides	35.5	30.0	10.1	10.4	24.1	10.2
Poa species	35.7	29.9	26.5	22.0	51.5	43.7
Sitanion hystrix	0.6	2.3	1.6	0.3	7.7	10.8
Stipa comata			0.5	0.06	21.3	16.0
S. viridula						0.1
Total Grasses (kg/ha)	193.7	140.3	60.4	46.49	216.4	140.8
Forbs						
Achillea lanulosa	0.04	0.9				
Antennaria species	12.9	17.3	1.8	0.3	0.2	0.1
A. microphylla	10.7	1.8		0.1	1.1	3.3
Arenaria fendleri	0.1					
Artemisia ludoviciana	0.1					
Astragalus diversifolius	1.8	2.3	0.2	0.1	1.2	0.7
A. purshii	2.2	1.5	1.1	1.1	0.6	0.6
Balsamorhiza sagittata			2.0		0.6	1.8
Chaenactis douglasii	2.2	1.0		0.8	0.2	0.04
Chenopodium species	0.1		0.1			0.1
Comandra umbellata	28.6	14.5	1.2	4.1	8.4	3.8
Cruciferae species	0.9	2.0	0.2	0.4	0.5	0.8
Cryptantha sericea	14.9	5.3	6.2	4.7	8.0	10.9
Erigeron eatonii	7.2	2.5	0.3	0.1	3.5	1.0

Table 3-31. (Continued)

Species	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Caged	Uncaged	Caged	Uncaged	Caged	Uncaged
Plots (N)[1/]	(45)	(45)	(79)	(81)	(73)	(77)
Eriogonum lonchophyllum	6.4	5.6	1.9			
E. umbellatum	23.6	14.8				
Haplopappus acaulis	26.1	28.9		21.9		
H. nuttallii	4.9	2.9	4.1	3.5	4.7	1.1
Hedysarum boreale	12.3	10.5			0.4	1.7
H. utahensis	0.4	4.9				
Heterotheca villosa					1.2	0.3
Ipomopsis aggregata	1.3	1.1	0.6	2.0	0.8	1.6
Linum lewisii	2.8	1.4		0.1	0.7	0.04
Lupinus species					1.0	
Melitotus officinalis						0.1
Penstemon species					0.1	0.6
P. caespitosus	2.6	0.7			2.7	1.8
Phylox hoodii	42.3	27.6	16.9	22.5	175.4	107.7
P. longifolia					0.1	
Physaria floribunda	8.2	7.7	2.5	1.6	1.9	4.2
Salsola kali				0.2		
Senecio species		0.3	0.2			0.1
S. multilobatus	1.3	0.2	2.2	1.4	1.2	0.4
Sphaeralcea coccinea	1.5	2.0	0.1	0.3	2.9	6.9
Taraxacum officinale				0.05		
Unknown composite	3.1	2.4				
Unknown forb	28.6	43.0	4.5	3.6	1.5	4.9
Total Forbs (kg/ha)	247.14	203.1	46.1	68.85	218.9	154.58
Total Grass & Forbs (kg/ha)	440.8	343.4	106.5	115.3	435.3	295.4

1/ Differences in the number of plots sampled (N) result from the addition of new transects during 1981 and/or when caged plots have been disturbed and consequently are sampled as uncaged plots.

Table 3-32. Summary of One-way ANOVA Results Comparing Range Productivity Within Vegetation Types for 1981, Tract C-a[1/]

Vegetation Type	Caged		Uncaged	
	F	PR>F [2/]	F	PR>F [2/]
Mixed Brush				
Grasses	0.66	0.7248	1.76	0.0950
Forbs	0.38	0.9297	0.87	0.5448
Pinyon-Juniper				
Grasses	1.41	0.1503	1.33	0.1910
Forbs	2.18**	0.0104	1.09	0.3724
Sagebrush				
Grasses	3.20**	0.0001	1.64	0.0699
Forbs	2.90**	0.0005	1.52	0.1150

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 3-1.5.

[2/] PR>F represents the significance probability (α) associated with F.

Table 3-33. Comparison of Range Production (standing crop, dry weight, kg/ha) and Utilization (%) Estimates on and Near Tract C-a, 1978 through 1981[1/]

Vegetation Type	Standing Crop: Caged Plots (dry wt, kg/ha) 1978	1979	1980	1981	Standing Crop: Uncaged Plots (dry wt, kg/ha) 1978	1979	1980	1981	Utilization (Percent) 1978	1979	1980	1981
Mixed Brush (N)[2/]	(50)	(50)	(49)	(45)	(50)	(50)	(50)	(45)				
Grasses	99	140	159	194	69	85	111	140	30	39	30	28
Forbs	111	104	132	247	77	88	91	203	31	15	31	18
Total	210	244	291	441	146	173	202	343	30	29	31	22
Pinyon-Juniper (N)[2/]	(50)	(49)	(50)	(79)	(50)	(46)	(50)	(81)				
Grasses	26	34	43	60	13	26	36	46	50	24	16	23
Forbs	18	18	30	46	10	18	30	69	44	0	0	...[3/]
Total	44	52	73	106	23	44	66	115	48	15	10	...[3/]
Upland Sagebrush (N)[2/]	(50)	(50)	(49)	(73)	(50)	(48)	(50)	(77)				
Grasses	85	132	157	216	51	78	94	141	40	41	40	35
Forbs	40	42	62	219	29	29	37	155	28	31	40	29
Total	125	174	219	435	80	107	131	296	36	39	40	32

1/ Production values reported for the 1979 sampling period on Table 3-4 of the MDP Monitoring Report 5 were incorrectly transferred from Table 3-3. These values have been corrected herein. Differences between the monitoring report and the table for percent utilization during 1979 are due in part to this error in data transfer. Other slight differences result from use of recalculated correction factors, deletion of several shrub species from the analyses, and/or rounding of figures.

2/ Differences in the number of plots sampled (N) result when caged plots have been disturbed; consequently the plots do not function as protected sampling locations.

3/ Higher production recorded in uncaged as compared to caged plots; thus, no utilization has be calculated.

The two-way ANOVA comparing production between years exhibited no significant differences for grass production in caged plots (Table 3-34). However, significant differences were noted among years and transects for production in uncaged plots (Table 3-34). Grass production in uncaged plots was significantly higher in 1981 than in other years (Table 3-35). Variations in grass production among transects from 1978 through 1981 result in four transect groupings (Table 3-35). Due to the complex nature of these groupings, trends are unclear.

Utilization of the grass/forb stratum during 1981 was 22 percent, which is lower than the values obtained from 1978 to 1980 (Table 3-33). During 1981, grass utilization was two percent lower than in 1978 or 1980, and 11 percent lower than in 1979. Forb usage in 1981 was 13 percent lower than in 1978 or 1980, but was 3 percent higher than in 1979.

Since 1978, range production in the Mixed Brush vegetation type has steadily increased (Table 3-33). However, utilization remained relatively constant from 1978 to 1980 and decreased in 1981 (Table 3-33). The increase in production may be due to increased available moisture. Precipitation during the growing season has increased from 4.45 inches in 1978 to 9.47 inches in 1981 (Table 3-36). This increase in moisture over the years sampled corresponds with increased production within the Mixed Brush vegetation type. The reduced utilization noted for 1981 may be related to fluctuations in the grazing pressure exerted by wildlife and livestock. The population of feral horses was reduced during the 1981 sample period, which may account for a portion of this lower utilization. It does not appear that Tract C-a activities are related to this change in utilization.

b. Pinyon-Juniper - Herbaceous production within the caged plots averaged 106.5 kg/ha as compared to 115.3 kg/ha for the uncaged plots (Table 3-31). Higher production in uncaged plots is principally due to stemless goldenweed, a forb species which was not encountered on any caged plots and was only found on two uncaged plots. However, on Transect 42 (one of the new transects established in 1981) the production of stemless goldenweed on Plot 5 was 176.8 g/m^2 (1,768 kg/ha; Appendix 3-1.4). The production on the other uncaged plot (Plot 6 on Transect 5) was only 0.5 g/m^2 (5 kg/ha). If stemless goldenweed is excluded from the uncaged plots, forb production would be 47 kg/ha, resulting in a

Table 3-34. Summary of Two-Way ANOVA Results Comparing Range Productivity for 1978 through 1981, Tract C-a[1/]

Vegetation Type	Source of Variation: Years F	Years PR>F [2/]	Transects F	Transects PR>F [2/]
Plot Type - Caged				
Mixed Brush				
Grasses	2.13	0.0938	1.58	0.1274
Forbs	1.72	0.1592	1.51	0.1499
Pinyon-Juniper				
Grasses	4.39**	0.0049	2.10**	0.0197
Forbs	0.44	0.7301	3.10**	0.0006
Sagebrush				
Grasses	5.75**	0.0008	6.97**	0.0001
Forbs	1.12	0.3413	1.95*	0.0376
Plot Type - Uncaged				
Mixed Brush				
Grasses	6.50**	0.0003	2.27**	0.0220
Forbs	1.95	0.1182	1.83	0.0679
Pinyon-Juniper				
Grasses	13.40**	0.0001	1.17	0.3096
Forbs	0.67	0.5743	4.09**	0.0001
Sagebrush				
Grasses	7.48**	0.0001	3.59**	0.0003
Forbs	1.03	0.3813	1.85	0.0588

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 3-1.5.

[2/] PR>F represents the significance probability (α) associated with F.

Table 3-35. Results of Duncan's Multiple Range Tests for Significant Differences in Grass Production (kg/ha) (Years and Transects) Within Uncaged Plots of the Mixed Brush Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=377 MS=2513.14

GROUPING	MEAN	N	YEAR
A	65.103093	97	81
B	49.800686	107	80
B			
C B	43.114772	91	79
C			
C	34.104000	94	78

ALPHA LEVEL=.05 DF=377 MS=2513.14

GROUPING	MEAN	N	TRANSECT
A	70.821438	29	35
A			
B A	63.204237	39	32
B A			
B A C	59.899334	49	31
B A C			
B D A C	49.806038	42	33
B D A C			
B D A C	47.087372	49	3
B D A C			
B D A C	43.958854	43	34
B D C			
B D C	40.604450	53	2
D C			
D C	36.509839	40	1
D			
D	31.494318	45	4

Table 3-36. Average Rainfall[1/] (inches) Recorded at RBOSC Meteorological Sites from 1978 to 1981, Tract C-a and Vicinity

Month	Year 1978[2/]	1979[3/]	1980[4/]	1981[5/]
April	1.28	0.54	1.16	0.38
May	1.06	2.66	2.04	2.51
June	0.63	0.43	0.02	1.10
July	0.38	0.69	1.15	2.67
August	0.53	1.15	2.02	1.54
September	0.57	0.15	0.65	1.26
Total	4.45	5.62	7.04	9.46

[1/] Rainfall (Wedge Gauge) averaged between Sites 1, 2, and 3.

[2/] Data from MDP Monitoring Report 3 (RBOSC 1979a).

[3/] Data from MDP Monitoring Report 5 (RBOSC 1980).

[4/] Data from MDP Monitoring Report 7 (RBOSC 1981b).

[5/] Data are presented in Section 2.2 of this document.

more realistic total herbaceous production of 93.4 kg/ha, which is lower than the 106.5 kg/ha recorded on the caged plots. Wheatgrass and bluegrass species, as well as Indian ricegrass, accounted for the majority of grass production. On caged plots, grass production was 60.4 kg/ha (57 percent of the total), while grass production on uncaged plots was 46.5 kg/ha, which accounts for 40 percent of the total.

Statistical analyses of the 1981 data indicate significant differences for forb production in caged plots (Table 3-32). Although similar to most other transects, production on Transects 5 and 7 was significantly lower than Transects 43 and 6 (Table 3-37). These data illustrate the natural variability of the Pinyon-Juniper vegetation type in the vicinity of Tract C-a. As might be expected,

Table 3-37. Results of Duncan's Multiple Range Tests for Significant Differences in 1981 Forb Production (kg/ha) Within Caged Plots on Transects in the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=123 MS=2182.78

GROUPING			MEAN	N	TRANSECT
	A		85.384615	13	43
	A				
B	A		69.000000	5	6
B	A				
B	A	C	48.000000	10	36
B	A	C			
B	A	C	38.166667	6	46
B		C			
B		C	35.500000	8	49
B		C			
B		C	30.625000	8	19
B		C			
B		C	30.500000	6	17
B		C			
B		C	21.846154	13	12
B		C			
B		C	20.625000	8	42
B		C			
B		C	18.500000	4	48
B		C			
B		C	18.461538	13	40
B		C			
B		C	17.545455	22	16
B		C			
B		C	9.250000	4	11
B		C			
B		C	8.857143	7	37
		C			
		C	4.750000	8	5
		C			
		C	3.750000	4	7

species composition seems to play a roll in influencing production. Eight different forb species were encountered along Transect 43 compared to five on Transect 5 and four on Transect 12. Hood's phlox had the highest forb production in the caged plots of Transect 43 but was nonexistent on Transects 5 and 7.

Production on both the caged and uncaged plots was higher in 1981 than in previous years. Caged plots supported production averaging 107 kg/ha in 1981 compared to 44, 52, and 73 kg/ha for 1978, 1979 and 1980, respectively (Table 3-33). Production on the uncaged plots rose from 23 kg/ha in 1978 to the present level of 115 kg/ha (Table 3-33). The dominant grasses during 1981 were similar to those in past years; however, the dominant forbs (Hood's phlox and Cryptantha sericea) in 1981 were different from those recorded most often during previous sampling periods.

The results of the two-way ANOVA comparing production from 1978 through 1981 exhibited significant differences among years for grass production on both caged and uncaged plots (Table 3-34). Significant differences among transects were noted for grass production in caged plots as well as forb production in both caged and uncaged plots (Table 3-34). Grass production in caged plots during 1981 was similar to production in 1979 but significantly greater than in 1980 or 1978 (Table 3-38). Variations in grass production among transects over the four years results in two transect groupings (Table 3-38).

Transects 36, 5, and 16 are similar to six other transects but exhibit significantly lower production than that recorded on Transects 6, 17, and 37. It is interesting to note that forb production on caged plots is also high on Transects 37 and 6 (Table 3-39). It might be expected that high grass production would correspond to low forb production; however, Transects 6 and 37 have both high grass and forb production. Grass production (uncaged plots) is significantly higher in 1981 and 1980 than in the two previous years (Table 3-40). This may be related to a combination of increased moisture (Table 3-36) and reduced grazing pressure. Forb production on the uncaged plots of Transects 37 and 6 was significantly higher than on the remaining transects of the Pinyon-Juniper vegetation type (Table 3-41).

Table 3-38. Results of Duncan's Multiple Range Tests for Significant Differences (Years and Transects) in Grass Production (kg/ha) Within Caged Plots of the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=344 MS=689.24

GROUPING	MEAN	N	YEAR
A	31.911765	102	81
A			
B A	24.770000	80	79
B			
B	23.270000	100	80
B			
B	17.876364	77	78

ALPHA LEVEL=.05 DF=344 MS=689.24

GROUPING	MEAN	N	TRANSECT
A	40.177333	12	6
A			
A	35.218286	28	17
A			
A	32.246400	35	37
A			
B A	28.798519	27	19
B A			
B A	27.857143	21	11
B A			
B A	26.570909	44	7
B A			
B A	25.298182	33	12
B A			
B A	23.347826	23	40
B A			
B A	19.686286	14	18
B			
B	18.569692	52	36
B			
B	17.928276	29	5
B			
B	16.549854	41	16

Table 3-39. Results of Duncan's Multiple Range Tests for Significant Differences (Transects) in Forb Production (kg/ha) Within Caged Plots of the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=265 MS=1695.83

GROUPING	MEAN	N	TRANSECT
A	63.576000	15	37
A			
B A	45.926400	25	6
B			
B C	24.740952	21	19
C			
C	23.318000	36	36
C			
C	17.421053	19	40
C			
C	16.922240	25	17
C			
C	16.652941	34	12
C			
C	14.124167	48	16
C			
C	11.000000	12	11
C			
C	7.140000	20	5
C			
C	7.112000	16	7
C			
C	7.089778	9	18

Table 3-40. Results of Duncan's Multiple Range Tests for Significant Differences (Years) in Grass Production (kg/ha) Within Uncaged Plots of the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=327 MS=420.057

GROUPING	MEAN	N	YEAR
A	28.521739	92	81
A			
A	22.657801	89	80
B	16.302030	89	79
C	9.215111	72	78

Table 3-41. Results of Duncan's Multiple Range Tests for Significant Differences (Transects) in Forb Production (kg/ha) Within Uncaged Plots of the Pinyon-Juniper Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=236 MS=1432.42

GROUPING	MEAN	N	TRANSECT
A	63.116903	8	37
A			
A	52.448001	27	6
B	32.557029	42	36
B			
C B	28.233129	35	5
C B			
C B	27.153954	17	1[illegible]
C B			
C B	14.824813	34	17
C B			
C B	12.557164	13	40
C			
C	11.658359	29	16
C			
C	8.611386	14	11
C			
C	8.454882	26	12
C			
C	5.611281	2	18
C			
C	4.905391	4	7

The utilization of both grasses and forbs, as shown on Table 3-33, has been very erratic over the years. As discussed previously, forb production was unexpectedly high in uncaged plots during 1981. This causes a distorted picture of the utilization in the Pinyon-Juniper vegetation type. If the inordinately high production of stemless goldenweed is excluded from the uncaged plots, utilization of herbaceous species would be 12 percent, which is comparable to 1979 and 1980 usage (Table 3-33).

c. Sagebrush - Production within the caged plots averaged 435.3 kg/ha, as compared to 295.4 kg/ha for the uncaged plots (Table 3-31). Grass production was responsible for 50 percent of the total herbaceous production (216.4 kg/ha) within the caged and 48 percent (140.8 kg/ha) in the uncaged plots (Table 3-31). The wheatgrass species, and to a lesser extent, Indian ricegrass and the bluegrass species, contributed 76 and 69 percent of the grass production for caged and uncaged plots, respectively. Hood's phlox was responsible for 80 percent of forb production in the caged and 70 percent of forb production in uncaged plots. Fifty percent of the production of caged plots (218.9 kg/ha) and 52 percent of the production of uncaged (154.6 kg/ha) plots were due to forb species.

Statistical analysis of the 1981 data exhibited significant differences in grass and forb production in caged plots (Table 3-32). Grass production within caged plots was significantly higher on Transects 15, 28, and 30 than on 11 of the 12 other sagebrush transects (Table 3-42). Grass production on transects established in 1981 (45, 50, 47, 44, and 41) was similar to that recorded on most other sagebrush transects (Table 3-42). Production of forbs in caged plots on Transects 41, 44, and 45 was significantly higher than on nine of the remaining 12 transects (Table 3-43).

Production of herbaceous species within caged plots was much higher (435 kg/ha) in 1981 than in 1978, 1979, or 1980 (125, 174, and 219 kg/ha, respectively; Table 3-33). Production on uncaged plots more than doubled from 1980 to 1981 (131 kg/ha versus 296 kg/ha; Table 3-33). For the most part, the dominant grass species noted in 1981 were the same as those recorded in previous years, but the dominant forb species have been variable among years.

Table 3-42. Results of Duncan's Multiple Range Tests for Significant Differences in 1981 Grass Production (kg/ha) Within Caged Plots on Transects in the Sagebrush Vegetation Type, Tract C-a.

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=226 MS=6377.09

GROUPING	MEAN	N	TRANSECT
A	158.272727	11	15
A			
A	155.000000	10	28
A			
B A	125.769231	13	30
B			
B C	64.076923	13	20
C			
C	60.000000	23	45
C			
C	57.000000	17	50
C			
C	55.384615	13	10
C			
C	51.083333	12	39
C			
C	50.333333	12	8
C			
C	49.200000	15	14
C			
C	48.857143	21	47
C			
C	48.692308	26	44
C			
C	45.764706	17	38
C			
C	38.428571	21	41
C			
C	33.764706	17	22

Table 3-43. Results of Duncan's Multiple Range Tests for Significant Differences in 1981 Forb Production (kg/ha) Within Caged Plots on Transects in the Sagebrush Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=151 MS=62381.5

GROUPING	MEAN	N	TRANSECT
A	447.818182	11	41
A			
B A	312.000000	5	44
B A			
B A	302.538462	13	45
B			
B C	100.200000	10	10
B C			
B C	68.812500	16	20
B C			
B C	41.625000	8	50
C			
C	32.000000	31	38
C			
C	31.000000	1	28
C			
C	29.000000	4	30
C			
C	26.600000	5	22
C			
C	22.863636	22	39
C			
C	20.928571	14	8
C			
C	20.875000	24	47
C			
C	7.000000	1	15
C			
C	4.000000	1	14
C			
C	4.000000	1	32

The two-way ANOVA comparing production from 1978 through 1981 exhibited significant differences among years for production of grasses in both caged and uncaged plots. Significant differences among transects were noted for production of grasses in both caged and uncaged plots, and for forbs in caged plots (Table 3-34). Grass production in caged plots was significantly lower in 1978 than in subsequent sampling years and was significantly greater on Transects 15 and 28 than on the remaining eight transects (Table 3-44). Because Transects 15 and 28 are located in valley bottom sites, while the other transects are in upland areas, the differences noted for these transects substantiate the notion that much of the variability within the sagebrush vegetation type is a function of location (upland vs. valley bottom). Most of the production on valley bottoms sites results from grass species, primarily the wheatgrasses and Indian ricegrass. The greater production of grasses may be a result of increased moisture available in the deep alluvial soils. Forb production in caged plots on Transect 10 was similar to that exhibited on Transects 22, 20, 30, and 28, but significantly higher than on four of the remaining six transects (Table 3-45). Grass production on uncaged plots was significantly higher in 1979-81 than in 1978 (Table 3-46). Production on Transects 20, 39, and 38 was significantly lower than on Transect 30 (Table 3-46).

As noted in the discussion for the Mixed Brush type, utilization of the herbaceous species in the sagebrush type during 1981 was lower than in any other year (Table 3-33). Grass utilization was 5 percent lower in 1981 than in 1978 or 1980, and 6 percent lower than in 1979. The use of forb species in 1981 was 11 percent lower than in 1980, and 2 percent lower than in 1979. It is possible that utilization within the sagebrush type has decreased due to the lower grazing pressure from livestock and/or feral horses. The grazing allotments around Tract C-a have undergone a rest-rotation during 1980, and feral horse populations have decreased markedly during 1980 and 1981 (see discussion in Section 3.2).

Table 3-44. Results of Duncan's Multiple Range Tests for Significant Differences (Years and Transects) in Grass Production (kg/ha) Within Caged Plots of the Sagebrush Vegetation Type, Tract C-a.

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=479 MS=6148.47

GROUPING	MEAN	N	YEAR
A	73.578947	133	81
A			
A	62.000000	124	80
A			
A	59.621622	111	79
B	33.956774	124	78

ALPHA LEVEL=.05 DF=479 MS=6148.47

GROUPING		MEAN	N	TRANSECT
	A	122.481400	40	15
	A			
	A	107.319415	41	28
	B	70.832755	53	30
	B			
C	B	53.349000	56	14
C	B			
C	B	50.892174	46	20
C	B			
C	B	45.980571	49	39
C	B			
C	B	44.406105	38	10
C	B			
C	B	38.664480	50	8
C				
C		35.652308	65	22
C				
C		32.027111	54	38

Table 3-45. Results of Duncan's Multiple Range Tests for Significant Differences (Transects) in Forb Production (kg/ha) Within Caged Plots of the Sagebrush Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=343 MS=3081.26

GROUPING	MEAN	N	TRANSECT
A	60.217043	23	10
A			
B A	46.151810	42	22
B A			
B A	46.118909	44	20
B A			
B A C	38.006667	12	30
B A C			
B A C	35.274286	7	28
B C			
B C	28.120276	87	38
B C			
B C	23.859429	63	39
C			
C	17.610462	65	8
C			
C	12.280000	8	15
C			
C	10.400000	5	14
C			
C	4.000000	1	32

Table 3-46. Results of Duncan's Multiple Range Tests for Significant Differences (Years and Transects) for Grass Production (kg/ha) Within Uncaged Plots of the Sagebrush Vegetation Type, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=448 MS=1298.6

GROUPING	MEAN	N	YEAR
A	44.931818	132	81
A			
A	38.769400	121	80
A			
A	37.544423	100	79
B	23.221333	108	78

ALPHA LEVEL=.05 DF=448 MS=1298.6

GROUPING	MEAN	N	TRANSECT
A	53.378367	53	30
A			
B A	49.681636	33	28
B A			
B A	47.630200	55	15
B			
B C	34.163129	41	14
B C			
B C	33.499629	51	22
B C			
B C	32.147141	52	8
B C			
B C	31.545087	28	10
C			
C	30.979869	48	38
C			
C	30.086660	54	39
C			
C	22.183454	46	20

3.2 FAUNA

A. Small Mammal Studies

1. Objectives and Rationale

The objectives of the small mammal program are to determine the species presence and habitat affinity, and to provide indices of relative abundance of dominant small mammal species in sagebrush and Pinyon-Juniper habitats in control and treatment areas. Appreciable changes over time within these habitats are identified.

2. Methods

The methods followed for collection and analysis of these data were described in MDP Monitoring Report 5 (RBOSC 1980). Small mammal trapping is conducted annually at the same transects and plots in each of the areas.

3. Results and Discussion

The numbers of small mammal species captured per 100 trap nights in each of the study areas are presented in Table 3-47. Total small mammal captures for 1981 by date, habitat type, area, transect, and plot are presented in Appendix 3-2.1.

The deer mouse (Peromyscus maniculatus) continued to be the most frequently captured species in all trapping locations. The least chipmunk (Eutamias minimus) continued to be the second most frequently captured species in Treatment Area 5 and Control Area 6. These two species also were captured most frequently in all habitat types during baseline studies (RBOSP 1977). Other incidental species captured in 1981 were the golden mantled squirrel, the pinyon mouse, and the sagebrush mole. Low numbers of all of these species were captured during baseline studies (RBOSP 1977). The limited species diversity may be a function of habitat qualities, trap affinities of the various species, or a combination of both. Nevertheless, the species diversity has remained rather stable in Area 5 and Area 6 for three years. The yearly variation in the number of captures of dominant species in Area 5 and Area 6 is within expected ranges due to normal fluctuations in small mammal populations.

Table 3-47. Numbers of Small Mammal Species Live-trapped in Two Habitat Types in RBOSC Treatment Area 5 and Control Area 6 in 1979, 1980 and 1981 and in Treatment Area 7 in 1981[1/]

	Treatment Area 5						Treatment Area 7[4/]		Control Area 6					
	Individuals[2/]			Total Captures[3/]			Individuals	Total Captures	Individuals			Total Captures		
Species	1979	1980	1981	1979	1980	1981	1981	1981	1979	1980	1981	1979	1980	1981
Pinyon-Juniper Habitat														
Peromyscus maniculatus	8.3	11.1	10.5	17.2	18.3	20.4	0.6	0.6	31.1	18.3	18.2	55.6	38.3	29.2
P. truei	...	...	0.6	...	...	1.1	0.6	0.6	...	...	1.1	...	...	1.1
Eutamias minimus	5.0	5.0	10.5	7.2	7.2	10.5	3.3	3.3	0.6	1.7	7.2	0.6	1.7	7.2
Neotoma cinerea	0.6	...	...	0.6	...	...	...	...	...	...	...	...	...	...
Citellus lateralis	...	2.2	1.7	...	2.2	1.7	...	...	...	...	...	...	...	...
Sagebrush Habitat														
Peromyscus maniculatus	22.2	13.2	16.5	41.6	24.4	30.3	9.9	19.3	34.4	10.0	14.8	61.7	21.1	26.4
Eutamias minimus	5.0	8.9	8.3	5.0	8.9	9.4	...	...	0.6	6.1	10.5	0.6	6.1	11.0
Mustela frenata	...	...	...	...	...	...	...	...	0.6	...	...	0.6	...	...
Reithrodontomys megalotis	...	...	...	...	...	...	...	...	...	0.6	...	...	0.6	...
Lagurus curtatus	...	...	...	...	...	...	0.6	0.6	...	...	...	...	...	...

1/ See Figure 3-1 for location of treatment and control areas.

2/ Numbers of separate individuals captured per 100 24-hour trapping periods.

3/ Number of total captures per 100 24-hour trapping periods.

4/ Treatment Area 7 first established in 1981.

... Indicates that species was not captured during the sample period.

the number of captures of dominant species in Area 5 and Area 6 is within expected ranges due to normal fluctuations in small mammal populations.

The reason for the low capture rate for all species in Treatment Area 7 is unknown. Phytosociological differences among the three study areas (Section 3.1C) do not appear to be great enough to account for the differences between the small mammal capture rate in Area 7 and those in Areas 5 and 6. Results of continued small mammal trapping in the three study areas may aid in the identification of factors which account for this disparity in trap rates.

B. Avifauna Studies

1. Objectives and Rationale

The objectives of the avifauna program are to determine the presence, habitat affinity, relative density (number observed per hectare of habitat), and relative abundance of avifauna species in sagebrush and Pinyon-Juniper habitats within the Control and Treatment Areas. Appreciable changes over time within the habitats are compared.

2. Methods

The methods for collection and analysis of these data are described in RBOSC MDP Monitoring Report 5 (RBOSC 1980).

3. Results and Discussion

The densities of all avifauna species observed during June 1979, 1980, and 1981 in the Pinyon-Juniper and sagebrush habitats for the control and treatment areas are presented in Table 3-48. Relative abundance data are presented in Table 3-49. All 1981 avifauna observations are presented in Appendix 3-2.2.

Avifauna sightings have changed little since initation of sampling in 1979. Not all species are observed in all years. Most of the species observed infrequently are rare in the region and/or are not common to the habitat types being surveyed.

Table 3-48. Densities of Avifauna Species Observed during June Sampling in Two Habitat Types in RBOSC Treatment Area 5 and Control Area 6 in 1979, 1980 and 1981 and in Treatment Area 7 in 1981[1/]

Species	Pinyon/Juniper Habitat							Sagebrush Habitat						
	Treatment Area 5			Treatment Area 7[2/]	Control Area 6			Treatment Area 5			Treatment Area 7	Control Area 6		
	1979	1980	1981	1981	1979	1980	1981	1979	1980	1981	1981	1979	1980	1981
Sharp-shinned Hawk				.06										
Marsh Hawk		.06										.06		
American Kestrel													.06	
Mourning Dove	.11	.11			.07									
Common Nighthawk		.11										.06		
Broad-tailed Hummingbird						.07	.21			.07	.06		.06	.12
Hairy Woodpecker	.06													
Western Kingbird											.06			
Gray Flycatcher				.06	.07									
Cliff Swallow										.07	.06			
Scrub Jay						.21	.42							
Black-billed Magpie					.07									
Common Raven	.23				.35	.14		.07	.07			.06		.06
Pinon Jay					.07	1.89	.07							
Clark's Nutcracker						.21								
Mountain Chickadee	.11	.28	.23	.38	.28	.14	.14			.07				
Plain Titmouse				.06	.14									
Common Bushtit							.28							
White-breasted Nuthatch				.51		.14								
House Wren	.06		.34											
Sage Thrasher								.43	.22	.29			.18	.30
Robin							.07							
Mountain Bluebird	.34	.40	.23	1.41	.14	.07	.28				.64	.12	.30	
Blue-gray Gnatcatcher	.11	.28	.23										.12	
Solitary Vireo	.11			.26			.28							
Black-throated Gray Warbler	.51	.28	.56	1.22	.70	.35	1.26							
Virginia's Warbler			.11											
Brown-headed Cowbird	.40	.06	.06						.29				.06	
Western Tanager		.06												
Green-tailed Towhee	.23	.23	.11		.35		.28	.43	.65	1.01	.51	1.01	1.01	1.07
Rufous-sided Towhee		.11				.49								
Vesper Sparrow											.19		.30	
Chipping Sparrow	.56	.23	.90	.83	.63	.70	.91				.96			
Brewer's Sparrow		.34			.42		.14	3.55	2.17	4.57	3.46	2.96	2.25	4.67
Total density of all species per hectare	2.83	2.55	2.77	4.79	3.29	4.41	4.34	4.48	3.40	6.08	5.94	4.27	4.34	6.22
Total number of species observed	12	13	9	9	12	11	12	4	5	6	8	6	9	5

1/ Values represent number of sightings of each species per hectare; not all species were seen in all years.

2/ Area 7 first sampled during 1981.

Table 3-49. Relative Abundance of Avifauna Species Observed in Two Habitat Types in RBOSC Treatment Area 5 and Control Area 6 in 1979, 1980 and 1981 and in Treatment Area 7 in 1981. [1/]

	Pinyon/Juniper Habitat							Sagebrush Habitat						
	Treatment Area 5			Treatment Area 7 [2/]	Control Area 6			Treatment Area 5			Treatment Area 7	Control Area 6		
Species	1979	1980	1981	1981	1979	1980	1981	1979	1980	1981	1981	1979	1980	1981
Sharp-shinned Hawk				.01										
Marsh Hawk		.02										.01		
American Kestrel													.01	
Mourning Dove	.04	.04					.02							
Common Nighthawk		.04										.01		
Broad-tailed Hummingbird						.02	.05			.01	.01		.01	.02
Hairy Woodpecker	.02													
Western Kingbird											.01			
Gray Flycatcher				.01	.02									
Cliff Swallow										.01	.01			
Scrub Jay						.05	.10							
Black-billed Magpie					.02									
Common Raven	.08				.11	.03		.02	.02			.01		.01
Pinon Jay					.02	.43	.02							
Clark's Nutcracker						.05								
Mountain Chickadee	.04	.11	.08	.08	.09	.03	.03			.01				
Plain Titmouse				.01	.04									
Common Bushtit							.06							
White-breasted Nuthatch				.11		.03								
House Wren	.02		.12											
Sage Thrasher								.10	.06	.05			.04	.05
Robin							.02							
Mountain Bluebird	.12	.16	.08	.29	.04	.02	.06				.11	.03	.07	
Blue-gray Gnatcatcher	.04	.11	.08										.03	
Solitary Vireo	.04			.05			.06							
Black-throated Gray Warbler	.18	.11	.20	.25	.21	.08	.29							
Virginia's Warbler			.04											
Brown-headed Cowbird	.14	.02	.02						.09				.01	
Western Tanager		.02												
Green-tailed Towhee	.08	.09	.04		.11	.11	.06	.10	.19	.17	.08	.24	.23	.17
Rufous-sided Towhee		.04												
Vesper Sparrow											.03		.07	
Chipping Sparrow	.20	.09	.33	.17	.19	.16	.21				.16			
Brewer's Sparrow		.14			.13		.03	.79	.64	.75	.58	.69	.52	.75

1/ Values represent number of sightings of each species per hectare divided by the total number of sightings of all species per hectare; not all species were seen in all years.

2/ Area 7 first sampled during 1981.

Species indicative of the Pinyon-Juniper habitat type are the Mountain Chickadee, Mountain Bluebird, and Black-throated Gray Warbler. The densities of these species have varied among the sample years, with the numbers of some species declining and others increasing. The Pinyon-Juniper habitats are somewhat dissimilar in the three areas in which avifauna are censused (see Section 3.1C Phytosociology). These dissimilarities may account, in part, for the different species observed in the three study areas. For example, the Blue Gray Gnatcatcher has been observed in Treatment Area 5 but not in Control Area 6. These differences are typical and expected when comparing different geographic areas.

Common species in the sagebrush habitat are Green-tailed Towhee and Brewer's Sparrow, both of which are indicative of shrublands. The Green-tailed Towhee may be found in many types of shrublands, while the Brewer's Sparrow is nearly always associated with sagebrush. Overall densities of avifauna species in the sagebrush habitats are very similar among the study areas for the years sampled.

The high variability of avifauna populations from year to year precludes drawing any firm conclusions regarding the effect of tract development on avifauna.

C. Mule Deer Density

1. Objectives and Rationale

Mule deer (Odocoileus hemionus) is the most important game species in Colorado in terms of recreational use and money expended by hunters. The Piceance Creek Basin is the wintering area of one of the largest migratory mule deer herds in the U.S. Tract C-a is within the Piceance Creek Basin which, for the most part, corresponds to the Colorado Division of Wildlife's (CDOW) Game Management Unit 22.

Moderate to high numbers of mule deer occur on and in the vicinity of Tract C-a during the winter and migration periods. Deer are uncommon around Tract C-a during the summer.

Consideration of the possible effects of Tract C-a development on mule deer is an integral part of RBOSC's Fish and Wildlife Management Plan. The objectives

of RBOSC's mule deer monitoring program are to obtain indices of mule deer density in a 9 x 9 mile (81 sq. mi) study area centered on Tract C-a (tract and 3 mile boundary), to compare indices of mule deer density from the study area with those from Game Management Unit 22 and, if possible, to compare differences in mule deer densities within various portions of the study area.

2. Methods

Mule deer densities can be estimated from pellet group density data because mule deer daily defecation rates are reasonably uniform (Neff 1968). The number of pellet groups per unit area, days of use by deer, and deer per unit area in the RBOSC study area are determined as described by Overton (1971). The methods followed for collection and analysis of these data are described in RBOSC MDP Monitoring Report 1 (RBOSC 1978a).

Mule deer pellet groups have been counted every spring and fall since 1978. The RBOSC mule deer study area is composed of nine blocks, each 9 square miles in extent. Within each block are seven quarter-section sampling units, which were randomly selected during the design of the study. Pellet counts are made in 20 permanent plots within each of these 63 quarter-section sampling units, for a total of 1260 plots.

3. Results and Discussions

Deer density estimates, based on pellet group counts, for the MDP monitoring period are presented in Table 3-50. Detailed data on each plot for the 1981 September sampling period are presented in Appendix 3-2.3. Duncan's Multiple Range Test results on all pellet group data collected to date also are presented in Appendix 3-2.3.

Deer enter the study area in the fall generally as a result of increasing snow depth or inclement weather which forces them to abandon higher elevation summer ranges. Because of individual tolerances to winter conditions, the deer leave higher elevations, enter the study area and move out of the study area over a variable period of time. Depending on weather conditions, migrating deer begin arriving in the area in October, and the majority of the deer reach the study

Table 3-50 Estimated Number of Mule Deer Per Square Mile by Block of the RBOSC Study Area for Four Winter and Four Summer Periods 1977-1981 And Basic Habitat Type Descriptors by Block

	Estimated Number of Deer Per Square Mile[1]										Habitat Type Descriptors								
	Winter Period[2]					Summer Period[3]					Mean	Mean[4]	Mean[5]	Vegetation Type[6] By Percent					
Block	77-78	78-79	79-80	80-81	Avg.	78	79	80	81	Avg.	Elevation	Slope	Aspect	MB	SB	PJ	MP	SP	OT
1	63	62	32	56	53.3	25	19	11	19	18.5	7300	22	SE	61.4	8.6	0.0	21.4	3.6	5.0
2	47	72	30	24	43.3	29	5	25	9	17.0	6700	11	E	0.7	20.0	31.4	20.7	27.1	0.0
3	63	33	23	15	33.5	23	7	18	4	13.0	6500	12	SE	0.0	61.4	7.1	12.1	19.3	0.0
4	43	28	28	49	37.0	13	7	17	20	14.3	7500	22	E	67.1	6.4	3.6	7.1	3.6	12.1
5	100	72	49	23	61.0	18	21	14	23	19.0	6900	13	SE	20.0	22.1	6.4	20.7	29.3	1.4
6	64	55	49	37	51.3	12	7	4	8	7.8	6500	15	SE	1.4	8.6	17.9	45.0	25.7	1.4
7	39	24	11	21	23.8	7	12	17	12	12.0	7500	27	S	84.3	2.1	0.0	2.1	0.0	11.4
8	31	25	21	16	23.3	7	7	4	2	5.0	7000	17	SE	20.7	29.3	3.6	27.8	15.0	3.6
9	9	18	14	9	12.5	5	20	2	5	8.0	6700	17	S	3.6	22.9	8.5	43.6	21.4	0.0
Avg.	51.0	43.2	28.6	27.8	37.7	15.4	11.7	12.4	11.3	12.7	6950	17.3	SE	28.8	20.2	8.7	22.3	16.1	3.9

1/ Based on pellet group counts with a defecation rate of 13 pellet groups per deer per day.

2/ Based on an average of 165 days in the winter accumulation period.

3/ Based on an average of 120 days in the summer accumulation period.

4/ Number represents average difference from horizontal in degrees for 140 plots in each block and includes all horizontal plots.

5/ Compass directions south, southeast, and east are represented by the letters S, SE and E, respectively.

6/ Vegetation types are represented by: MB = Mixed Brush; SB = Sagebrush; PJ = Pinyon-Juniper; MP = Mixed Brush/Pinyon-Juniper; SP = Sagebrush/Pinyon-Juniper; OT = other vegetation type.

area by December 1. During moderate to severe winters, deer may remain at lower elevations throughout the winter.

During mild winters, deer often inhabit a range of elevations in response to variations in snow depths. Spring migrations away from the study area are also dependent upon weather conditions but generally occur more rapidly than the fall migration, once migration is initiated. The majority of the deer leave the study area by April 1, with few deer remaining in the area during the summer.

Because the exact number of days that deer are in the study area is unknown, the deer density indicies are computed using an average number of days that deer should be present during an average winter. Pellet counts are made in May, after the majority of deer have left the area, to obtain an index of winter use; and in September, before the majority of deer arrive, to obtain a qualitative index of deer numbers during the summer.

Mule deer densities determined using pellet group counts are limited in that such indices cannot indicate the actual numbers of deer present in an area, but only the average number of "deer-use" days in each area during the accumulation period. In addition, such indices cannot establish deer use over time. For example, evidence indicating one deer in an area for ten days cannot be differentiated from that indicating ten deer in an area for one day. Consequently, if a severe winter precludes deer use of an area for much of the winter pellet group accumulation period, a very high deer use of the area may be experienced for a short time in the early spring. Pellet group counts, nevertheless, might indicate an average deer use, an indication which would be misleading in this case.

The deer density estimates presented in Table 3-50 show an overall decline in winter use of the study area since the counts were initiated in 1978. The Piceance Basin deer herd was fairly large in the fall of 1978, and the ensuing winter caused severe deer mortality. As much as one half of the deer herd including 80-90 percent of the fawns born in 1978, was lost to starvation and exposure in the winter of 1978/79 (John Gray, CDOW, personal communication). The effects of this mortality may be experienced for four years until the

winter of 1982-83. The reduction of the yearling age class in the summer of 1979, due to the die-off of 1978 fawns during the 1978/79 winter may have resulted in a low first year reproductive class and limited fawn production in 1980. Some pregnant does surviving the winter of 1978-79 may have had still births, and live fawns born to these does may have been very weak and died shortly after birth. The low fawn production in the summer of 1979 may have had similar effects on the 1980 reproductive class, resulting in another year of lowered fawn production in 1981.

Analyses of the mule deer density data collected to date indicate that populations are beginning to rebound from the low point reached after the 1978/79 winter. Using a two-way analysis of variance procedure to compare average mule deer densities on all blocks during the winter sampling period for the four years sampled to date reveals that, although average densities continued to decline in 1981, this decline was not statistically significant (Table 3-51). Densities had declined significantly for two consecutive years prior to 1981; the largest decline occurred between 1979 and 1980. Although the die-off occurred during the winter pellet group accumulation period of 1978-1979, the high density of deer in the fall of 1978 resulted in an estimate of density of deer in the spring of 1979 which did not accurately reflect the extent of the die-off. Only after the sampling in the spring of 1980 was the full impact of the die-off exhibited by the density estimates.

Evidence that deer populations are increasing can be found by examinations of 1981 mule deer density data as well. Limited snow accumulation during the winter of 1980-81 allowed the deer to winter at elevations which were higher than normal, resulting in a reduction of use of the study area. Consequently, density estimates for 1981 may have been somewhat depressed. The regional population of deer for the 1981 winter period may have been larger than that indicated by the density estimates for the study area. This hypothesis is substantiated by examining the results of analyses of variance procedures comparing 1981 winter density estimates by block and procedures comparing winter density estimates for individual blocks over the four years which have been sampled (Appendix 3-2.3). Winter density estimates were higher in 1981 than in 1980 in only three blocks within the study area: Blocks 1, 4, and 7. These blocks are at higher elevations than the rest of the blocks and are near summer range.

Table 3-51. Duncan's Multiple Range Test Results for Mule Deer Pellet Group Counts During the Winter Sampling Period for 1978, 1979, 1980, and 1981.

TWO-WAY MODEL I ANALYSIS OF VARIANCE
COMPARING BLOCKS AND YEARS AS MAIN EFFECTS
OVER THE WINTER SAMPLING PERIODS

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PELLET

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=5004 MS=0.441336

GROUPING	MEAN	N	YEAR
A	0.403968	1260	78
B	0.343651	1260	79
C	0.224603	1260	80
C			
C	0.219841	1260	81

Density estimates for the 1981 winter use period were significantly higher in Blocks 1 and 4 than all other blocks with the exception of Block 6. RBOSC is currently measuring accumulated snow depths at three elevations around Tract C-a. Data from this study should provide information regarding the influence of snow depths on deer movement.

Considering the effects of winter conditions on mule deer movements and overall herd stability, the impacts resulting from the development activity on Tract C-a to date on mule deer are difficult to assess. Continued data collection and scrutiny should yield more information on deer behavior in the western Piceance Basin, and increase the feasibility of identifying any development-related impacts.

D. Mule Deer Road Kill Survey

1. Objectives and Rationale

The objective of this program is to determine mule deer mortality due to collisions with vehicles along Rio Blanco County Road 24, from the Piceance Creek Road to Tract C-a.

2. Methods

The methods for collection of these data are described in RBOSC MDP Monitoring Report 5 (RBOSC 1980).

3. Results and Discussion

The locations of deer killed by collisions with vehicles along County Road 24 during 1981 are shown in Figure 3-2. Data on all observed deer road kills since 1979 are presented in Appendix 3-2.4. Total numbers of road kills by year for the three years of sampling are listed on Table 3-52.

Even though deer densities along County Road 24 varied greatly from 1979 to 1981, the number of road kills did not. It is likely that some deer road kills

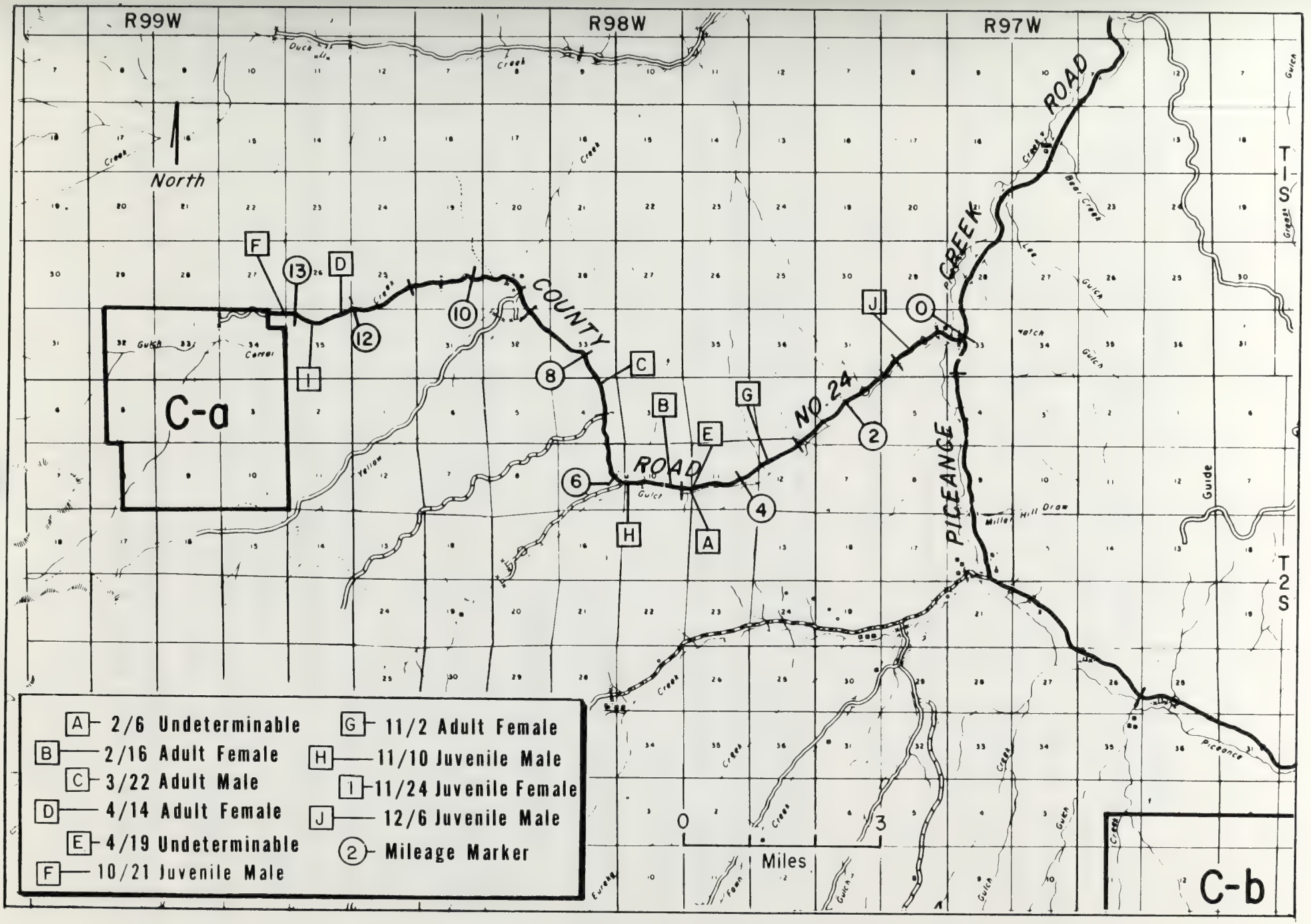


Figure3-2. Locations of Mule Deer Road Kills Along County Road #24 During 1981

Table 3-52. Mule Deer Road Kill Data 1979-81.

Year	Number of Road Kills	Sex		Age		Undeterminable[1/]
		Female	Male	Juvenile	Adult	
1979	12	8	4	4	8	0
1980	13	10	3	3	10	0
1981	10	5	3	4	4	2

[1/] Sex and age could not be determined due to carcass condition.

always will be associated with heavy traffic in areas of high deer density. Presentations designed to educate drivers of the problems of driving to and from Tract C-a are part of the mandatory safety training program for all RBOSC employees. Methods to advise non-employees of the deer hazards are being investigated.

E. Feral Horse Abundance

1. Objectives and Rationale

Feral horses occur on and in the vicinity of Tract C-a. These horses are protected under federal law and are under the jurisdiction of the BLM. Feral horses compete with cattle and, to a lesser extent, with mule deer for available forage. The objective of feral horse monitoring studies is to provide qualitative information concerning the status of feral horses in the RBOSC study area (note: the feral horse study area is the same as that for the mule deer).

2. Methods

The methods followed for collection of data on feral horses are described in RBOSC MDP Monitoring Report 1 (RBOSC 1978a).

3. Results and Discussions

Feral horses on the Tract C-a study area were counted from a helicopter in March 1981. Ten bands of horses totaling 57 individuals were observed (Figure 3-3). This number is less than the 99 horses observed in the 1979 count and the 120 observed in 1980. The results of feral horse aerial surveys since 1978 are contained in Appendix 3-2.5. Foal success was determined by a road count survey separate from the aerial survey. Foal success for 1981, expressed in age ratios, is shown in Table 3-53.

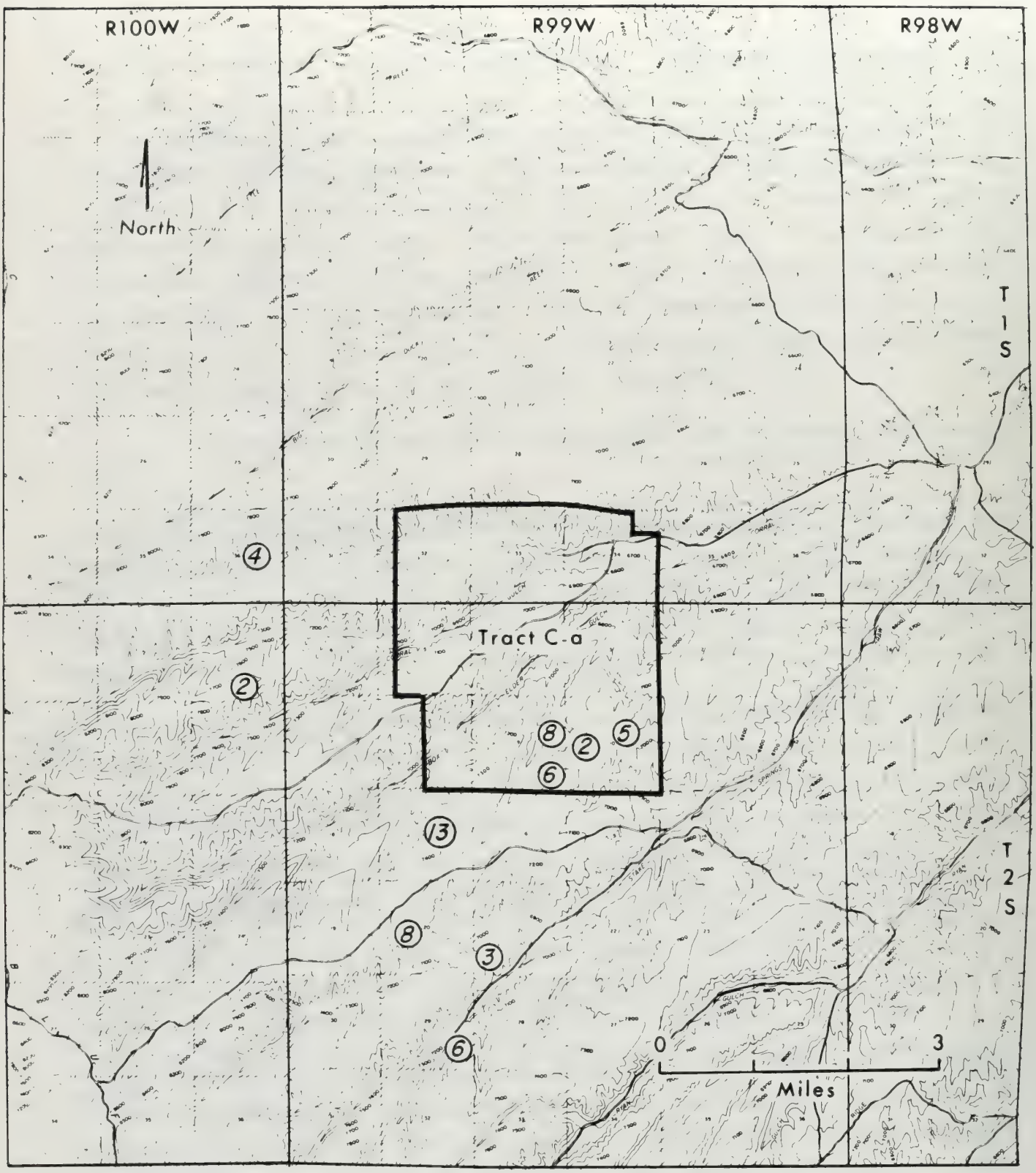
Table 3-53. Number of Feral Horses Observed During the March 1981 Aerial Census

Age Class	Number Observed	Percentage of Total Observed
Adult and Yearling	45	73.8
Foal	16	26.2

Age ratios for 1980 were 74.3 percent adults and yearlings, and 25.7 percent foals. Foal success was apparently similar for the two years. The BLM conducted horse roundups throughout the Piceance Basin in September of 1980. This is probably the reason for the reduction in the number of horses observed in March 1981. Another factor in the reduced count may have been the limited snow cover during the census period, which allowed the horses to move to higher elevations outside the study area.

F. Threatened, Endangered, and Protected Species

Baseline, interim, and MDP environmental studies indicate that Tract C-a and the surrounding area does not provide critical habitat for any state or federally protected endangered wildlife species. The only species in these categories regularly observed in the vicinity of Tract C-a is the bald eagle. This species is occasionally seen foraging in the area and feeding on dead deer during winter months.



(7) *Number of Horses in Band and Approx. Location of Band*

Figure 3-3: Feral Horses Observed During the March/1981 Aerial Census

Golden eagles and other raptors protected in Colorado were seen during the reporting period. Some of these species are year long residents and may nest in the area. No nests are known to occur near development activities.

3.3 SUMMARY

The components of the Terrestrial Monitoring Program examined during the 1981 reporting period include vegetation type mapping and stress, browse condition and utilization, phytosociology, range production and utilization, small mammal, avifauna, mule deer, and feral horse studies.

The distribution of plant communities during 1981 was compared with that established during baseline studies and as a result of analysis of 1978 color aerial photographs. Changes noted on Tract C-a and within a five mile perimeter are the result of oil and gas exploration as well as Tract C-a related construction including the airstrip, the road to off-tract property, coreholes, and the dewatering/reinjection system. Small amounts of Pinyon-Juniper and sagebrush vegetation have been affected by these activities but no major changes in plant community distribution have resulted from activities other than construction related to Tract C-a development. Analysis of 1981 color infrared photographs is not complete; consequently, results will be reported in subsequent MDP Monitoring Reports

Browse studies indicated that the weighted average percent utilization ranged from 5 percent in the sagebrush to 9 percent in the Pinyon-Juniper vegetation type. Utilization increased in the Mixed Brush and sagebrush types but decreased slightly in the Pinyon-Juniper habitat type relative to 1980 data. Results of a two-way ANOVA using arcsine transformed estimates of leader utilization among years (1978-1981) by individual browse species indicated significant differences ($\alpha \leqq 0.025$) in use of serviceberry (Amelanchier utahensis) within the Mixed Brush type; sagebrush (Artemisia tridentata), pinyon pine (Pinus edulis), bitterbrush (Purshia tridentata), mountain mahogany (Cercocarpus montanus), snowberry (Symphoricarpos oreophilus), and serviceberry within the Pinyon-Juniper type; and sagebrush within the sagebrush vegetation type. For the most part, all of these species experienced significantly lower browse leader usage in 1981 than during 1978. This lower leader use in 1981 relative to 1978 is probably a result of the decline in the mule deer herd due to the harsh 1978-79 winter.

Range condition ratings based on hedging class are for the most part an improvement over what was exhibited in 1980. These meliorations are due to lower browse utilization over the years. Because the RBOSC browse studies are designed to census the same shrubs every year, any large changes in range condition ratings based on hedging class would not be found. However, analyses of these data over years should show trends in range condition ratings.

Phytosociological studies were conducted within the Pinyon-Juniper and sagebrush vegetation types in Treatment Area 7, which is located just east of RBOSC's off-tract land. Average coverage of trees and shrubs within the Pinyon-Juniper habitat type was 44.2 percent. Pinyon pine (Pinus edulis) and juniper (Juniperus osteosperma) accounted for almost all of this cover. Sagebrush (Artemisia tridentata) had the highest average density (1,100 stems per hectare) of any tree or shrub surveyed in the Pinyon-Juniper area (density averaged 1,953 stems per hectare for woody species). Herbaceous coverage averaged 16 percent, with grasses accounting for 12.3 percent and forbs 3.7 percent of this total. Dominant grasses were bluegrass (Poa) and wheatgrass (Agropyron) species while Hood's phlox (Phlox hoodii) and Cryptantha sericea were the most prevalent forbs. Statistical comparisons of arcsine transformed coverage estimates for grasses and forbs showed no significant differences among transect within Area 7 ($\alpha \leq 0.05$).

Coverage of trees and shrubs in the sagebrush vegetation type averaged 22.3 percent while average density was 11,287 stems per hectare. Sagebrush was the most prominent species, averaging 20.5 percent cover and 9,573 stems per hectare. Douglas rabbitbrush (Chrysothamnus viscidiflorus) was a subordinate shrub, averaging 1,280 stems per hectare and 1.4 percent cover. The grass-forb stratum averaged 30 percent coverage. Grasses, primarily the bluegrass, wheatgrass, and needle-and-thread (Stipa comata) species, accounted for 21.7 percent of this total cover. Forb coverage was 8.4 percent most of which was made up by Hood's phlox and, to a lesser extent, scarlet globemallow (Sphaeralcea coccinea) and Cryptantha sericea. As in the Pinyon-Juniper discussion, there were no significant differences ($\alpha \leq 0.05$) for the arcsine transformed grass and forb coverage data in the sagebrush habitat type among transects within Area 7.

Range productivity and utilization studies indicated that production ranged from 106.6 kg/ha in the Pinyon-Juniper vegetation type to 440.8 kg/ha in the Mixed Brush type. With the exception of the Pinyon-Juniper type, forb production exceeded grass production. Wheatgrass (Agropyron) species, Indian ricegrass (Oryzopsis hymenoides) and bluegrass (Poa) species were the dominant grasses in all three vegetation types. For the most part, forb species responsible for the majority of the production were similar for all three habitat areas. Hood's phlox (Phlox hoodii), stemless goldenweed (Haplopappus acaulis), bastard toadflax (Comandra umbellatum), and sulfur eriogonum (Erigonum umbellatum) were predominant on the Mixed Brush area. The Pinyon-Juniper habitat type was dominated by Cryptantha sericea, stemless goldenweed, and Hood's phlox. The dominant forb species within the sagebrush vegetation type was Hood's phlox.

Statistical comparisons of range production among 1981 transects within the three vegetation types indicate significant differences ($\alpha \leqq 0.025$) for forb production within caged plots in the Pinyon-Juniper habitat type, and for grass and forb production within caged plots in the sagebrush vegetation type. Comparisons among years (1978-1981) using a two-way ANOVA indicate significant differences in grass production for caged and uncaged plots in all three vegetation types. An exception was grass production within caged plots in the Mixed Brush habitat type. Grass production in 1981 was significantly greater than during 1978 in all of the vegetation types.

Utilization of the Mixed Brush and sagebrush vegetation types declined in 1981 when compared to previous years. Within the Mixed Brush type, usage declined from a three year high of 31 percent recorded in 1980 to 22 percent in 1981. Utilization in the sagebrush vegetation type decreased from 40 percent in 1980 to 32 percent in 1981. Utilization for the Pinyon-Juniper area could not be determined because of a higher total herbaceous production in uncaged than in caged plots. This appears to be due to an extremely inflated forb production caused by stemless goldenweed (Haplopappus acaulis) (176.8 g/m^2 (1,768 kg/ha) on one uncaged plot). If stemless goldenweed is excluded from the uncaged plots (it was not encountered on any caged plots), the total production in uncaged plots is lower than that for caged plots. The result is a 12 percent usage, which is comparable to use in the previous two years.

Small mammal trapping studies were conducted in 1981 in sagebrush and Pinyon-Juniper habitats in control and treatment study areas on and near Tract C-a. These studies are designed to determine the species presence and habitat affinity, and to provide indices of relative abundance of dominant small mammal species.

In 1981, the deer mouse (Peromyscus maniculatus) continued to be the most frequently captured species in all trapping locations. The least chipmunk (Eutamias minimus) continued to be the second most frequently captured species in Treatment Area 5 and Control Area 6. Other species captured in 1981 were the golden mantled squirrel, the pinyon mouse, and the sagebrush mole. The limited species diversity may be a function of habitat qualities, trap affinities of the various species, or a combination of both. Species diversity has remained rather stable in Area 5 and Area 6 for three years. The yearly variation in the number of captures of dominant species in Area 5 and Area 6 is within the expected range due to normal fluctuation in small mammal populations. The reason for the low capture rate for all species in Treatment Area 7 is unknown. Phytosociological differences do not appear to be great enough to account for the differences between the small mammal capture rate in Area 7 and those in Areas 5 and 6.

The objectives of the avifauna program are to determine the presence, habitat affinity, relative density (number observed per hectare of habitat), and relative abundance of avifauna species in sagebrush and Pinyon-Juniper habitats within control and treatment areas.

Avifauna sightings have changed little since initiation of sampling in 1979. Not all species are observed in all years. Most of the species seen infrequently are not abundant in the region and/or are not common to the habitat types being surveyed.

Species indicative of the Pinyon-Juniper habitat type are the Mountain Chickadee, Mountain Bluebird, and Black-throated Gray Warbler. Densities of these species have varied among the sample years, with the numbers of some species declining and others increasing. The Pinyon-Juniper habitats are somewhat dissimilar in the three areas in which avifauna are censused (see

Section 3.1C of this report). These dissimilarities may account, in part, for the different species observed in the three study areas. These differences are typical and expected when comparing geographic areas. Common species in the sagebrush habitat are the Green-tailed Towhee and Brewer's Sparrow. Overall densities of avifauna species in the sagebrush habitats are very similar among the study areas for the years sampled.

The high variability of avifauna populations from year to year precludes drawing any firm conclusions regarding the effect of tract development on avifauna.

The objectives of RBOSC's mule deer monitoring program are to obtain indices of mule deer density in a study area centered on Tract C-a, to compare those indices with those from CDOW Game Management Unit 22 and, if possible, to compare differences in mule deer densities within various portions of the study area.

The deer density estimates for 1981 and previous years show an overall decline in winter use of the study area since the counts were initiated in 1978. The Piceance Basin deer herd was fairly large in the fall of 1978, and the ensuing winter caused severe deer mortality. As much as one half of the deer herd, including 80-90 percent of the fawns born in 1978, was lost to starvation and exposure in the winter of 1978/79 (John Gray, CDOW, personal communication). Analyses of the mule deer density data collected to date indicate that populations are beginning to rebound from this low point, however. Analysis of winter density indices for the four years sampled to date reveals that, although average densities continued to decline in 1981, this decline was not statistically significant. Densities had declined significantly for two consecutive years prior to 1981.

Evidence that deer populations are increasing can be found by examinations of 1981 mule deer density data as well. Limited snow accumulation during the winter of 1980-81 allowed the deer to winter at elevations which were higher than normal, resulting in a reduction of use of the study area. Consequently, density estimates for 1981 may have been somewhat depressed. This theory is substantiated by the fact that winter density estimates were higher in 1981

than in 1980 in only three blocks within the study area: blocks 1, 4, and 7. These blocks are at higher elevations than the rest of the blocks and are near summer range. The regional deer population thus may have been higher than indicated by the 1981 indices.

Considering the effects of winter conditions on mule deer movements and overall herd stability, the impacts resulting from the development activity on Tract C-a to date on mule deer are difficult to assess. Continued data collection and scrutiny should yield more information on deer behavior in the western Piceance Basin, and increase the feasibility of identifying any development-related impacts.

The objective of the mule deer road kill survey is to determine mule deer mortality due to collisions with vehicles along Rio Blanco County Road 24, from the Piceance Creek Road to Tract C-a. Ten road kills were observed in 1981. Even though deer densities along County Road 24 varied greatly from 1979 to 1981, the number of road kills did not. It is likely that some deer road kills always will be associated with heavy traffic in areas of high deer density.

Feral horses occur on and in the vicinity of Tract C-a. The objective of the feral horse monitoring studies is to provide qualitative information concerning the status of feral horses in the RBOSC study area. Feral horses were counted from a helicopter in March 1981. Ten bands of horses totaling 57 individuals were observed. This number is less than the 99 horses observed in the 1979 count and the 120 observed in 1980. The BLM conducted horse roundups throughout the Piceance Basin in September of 1980. This is probably the reason for the reduction in the number of horses observed in March 1981. Another factor in the reduced count may have been the limited snow cover during the census period, which allowed the horses to move to higher elevations outside the study area. Foal success was determined by a road count survey separate from the aerial survey. Foal success was apparently similar for 1980 and 1981.

LITERATURE CITED

Cole, G. P. 1963. Range survey guide. U.S.D.I., Grand Teton National History Association, Grand Teton National Park, Moose, Wyoming. 18 p.

Neff, D.J. 1968. The pellet group count technique for big game trend, census, and distribution: a review. J. Wildl. Manage. 32(3): 597-614.

Overton, W.S. 1971. Estimating the numbers of animals in wildlife populations. p. 403-456 in R. H. Giles, Jr. (Ed) Wildlife Management Techniques. Edward Bros., Inc., Ann Arbor, Michigan. (For the Wildlife Society).

Rio Blanco Oil Shale Company. 1978a. Modular development phase monitoring report 1, September 1977 - November 1977. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1978b. Modular development phase monitoring report 2, December 1977 - May 1978. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1979a. Modular development phase monitoring report 3, December 1977 - November 1978. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1979b. Modular development phase monitoring report 4, December 1978 - May 1979. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1980. Modular development phase monitoring report 5, December 1978 - November 1979. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1981a. Modular development phase monitoring program scope of work. Revision 6.1. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1981b. Modular development phase monitoring report 7, December 1979 - November 1980. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1981c. Modular development phase monitoring report 8, December 1980 - May 1981. Gulf Oil Corp. and Standard Oil Co. (Indiana).

Rio Blanco Oil Shale Project. 1977. Final environmental baseline report for Tract C-a and vicinity. Gulf Oil Corp. and Standard Oil Co. (Indiana).

SECTION 4
AQUATIC STUDIES

4.0 INTRODUCTION

The MDP Aquatic Monitoring Program is designed to provide information on aquatic ecosystems in the vicinity of Tract C-a and to identify and measure the potential effects of modular oil shale development on local aquatic biota. Table 4-1 lists the sampling frequency and the parameters measured at the six locations sampled.

The six sampling stations used for the 1981 MDP monitoring program are as follows (Figure 4-1):

- Station CG-1 at the USGS gaging station in Corral Gulch (east)
- Station YC-1 on Yellow Creek approximately 100 meters below the confluence of Stake Springs Draw and Corral Gulch
- Station YC-2 on Yellow Creek at the road crossing approximately 10 km upstream from the confluence of the White River and Yellow Creek
- Station YC-3 at the USGS gaging station in Yellow Creek, approximately 400 meters upstream from the confluence of Yellow Creek and White River
- Station WR-1 on the White River above its confluence with Yellow Creek
- Station WR-2 on White River below its confluence with Yellow Creek

Sampling for the MDP Aquatic Monitoring Program was initiated in October 1977 at Stations CG-1, YC-3, WR-1, and WR-2, which were reported previously as Stations 13, 20, 27 and 29, respectively. Two stations, YC-1 and YC-2, were added in 1981 and two, 14 and 21, were dropped. These changes were made to provide stations that are more representative of the aquatic habitat in the study area. This report provides the results of the 1981 MDP aquatic studies and comparisons of these results to those data collected during baseline studies (1974-1976) and previous years of the MDP aquatic monitoring studies.

Table 4-1. Aquatic Studies Monitoring Schedule

Parameter	Location	Frequency
ABIOTIC COMPONENTS:		
Physical Measurements	All Stations (see Figure 4.1)	3 Times/yr (April, July, October)
Total Dissolved Solids		
Stream Velocity and Flow		
Turbidity		
Dissolved Oxygen		
pH		
Specific Conductance		
Depth		
Width		
Stream Substrate		
Suspended Solids		
Temperature		
Alkalinity		
Basic Water Quality Measurements	All Stations	3 Times/yr (April, July, October)
Calcium		
Magnesium		
Potassium		
Sodium		
Bicarbonate		
Carbonate		
Chloride		
Nitrate		
Sulfate		
Fluoride		
Ammonia		
Total Phosphate		
Boron		
Silica (SiO_2)		
Iron		
Dissolved Organic Carbon		
Arsenic		
Selenium		
Vanadium		
Molybdenum		
Mercury		
Trace Water Quality	All Stations	Once/yr (October)
Aluminum		
Barium		

Table 4-1 (continued)

Parameter	Location	Frequency
Beryllium		
Bismuth		
Bromide		
Cadmium		
Chromium		
Copper		
Gallium		
Germanium		
Lead		
Lithium		
Manganese		
Nickel		
Strontium		
Titanium		
Zinc		
Zirconium		
BIOTIC COMPONENTS:		
Periphyton	All Stations	3 Times/yr (April, July, October)
Taxonomic Composition		
Relative Abundance		
Diversity		
Benthos	All Stations	3 Times/yr (April, July, October)
Taxonomic Composition		
Relative Abundance		
Diversity		

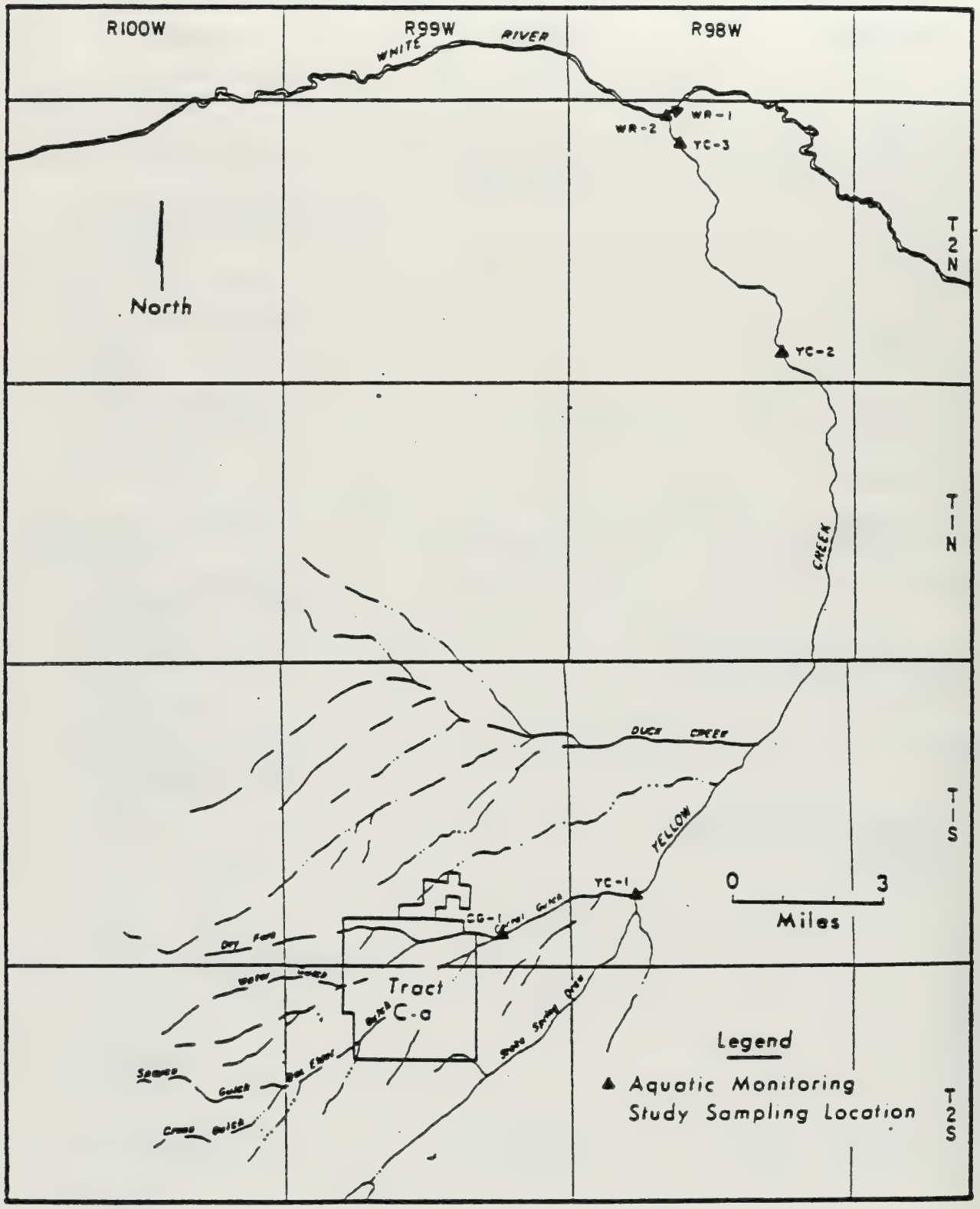


Figure 4-1. MDP Aquatic Monitoring Station Locations

4.1 ABIOTIC COMPONENTS

A. Physical Measurements

1. Objectives and Rationale

The physical measurements program is designed to monitor selected physical parameters at MDP aquatic sampling stations and to relate the data to water quality and aquatic biotic conditions. The parameters selected for monitoring are those which may be affected by project activities and which may influence the distribution, abundance, and composition of aquatic biota in the study area. Chemical parameters, such as dissolved oxygen, which were recorded in conjunction with the physical measurements, are also presented in this section.

2. Methods

The methods used to collect physical stream data are described in RBOSC MDP Monitoring Report 1 (RBOSC 1978).

3. Results and Discussion

A comparison of the measurements of physical parameters obtained during the 1981 MDP studies with the results from previous years (Tables 4-2 through 4-7) indicates much seasonal and year-to-year variability. In October 1981, the Corral Gulch (Station CG-1) pH (7.2) was well below the respective baseline values. Dissolved oxygen and conductivity values at Station YC-3 in October were below baseline ranges for these parameters. When compared to baseline conditions, April 1981 conductivity, alkalinity, and pH values were low at the White River control station, WR-1. April conductivity and pH readings for station WR-2 were also low. July water temperatures at Stations WR-1 and WR-2 (22 C) were in excess of temperatures recorded at these sites during the baseline study. Baseline data for Stations YC-1 and YC-2 are unavailable for comparison.

Table 4-2. Physical and Chemical Characteristics at Station CG-1 for RBOSC MDP Studies (1977-1981) and RBOSC Baseline Studies (1974-1976)

	PARAMETERS									
Date	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth (cm)	Velocity (m/s)
Baseline										
10-11/74	10	1,200	8.9	410	7.8	2	Sa,Gr	0.91	2.5	0.15
4/75	9	1,730	5.2	716	8.3	>1,000	Gr,Si	0.91	7.6	0.30
7-8/75	18	1,200	6.2	396	7.5	6	Gr,Sa	0.85	7.6	0.61
10/75	13	1,200	8.4	421	7.8	1	Gr,Sa	0.61	7.6	0.58
4/76	13	1,150	7.8	435	7.5	<1	Gr,Sa	1.2	10.2	0.43
7-8/76	15	1,200	7.1	381	8.0	4	Gr,Sa	0.91	7.6	0.64
MDP										
10/77	19	1,200	8.0	401	7.8	NA[2/]	Gr	1.1	5.1	0.21
4/78	17	1,500	5.1	584	8.3	60.0	Gr	1.1	15.2	0.61
7/78	15	1,400	6.6	302	8.1	NA	Gr,Sa	1.5	15.2	0.70
10/78	11	1,800	7.9	496	7.8	1.5	Gr	1.4	17.8	0.61
4/79	15	1,050	6.3	450	7.8	155	Gr	1.46	22.7	0.76
7/79	15	1,225	12.3	447	8.3	NA	Gr,Sa	2.29	10.2	0.37
10/79	17	1,325	7.2	413	8.1	12	Gr,Si	1.46	10.2	0.58
4/80	13	1,390	7.5	495	6.4	0.7	Gr,Sa,Si	1.55	6.9	0.44
7/80	16	1,305	7.8	465	7.6	NA	Gr,Sa,Co	1.6	9.1	0.68
10/80	10	1,500	9.8	520	7.6	0.8	Gr,Sa,Co	0.97	9.8	0.33
4/81	10	1,390	6.9	500	7.7	0.4	Gr	0.6	5.1	0.43
7/81	14	1,250	6.9	470	7.8	6.2	Gr,Co,Si	0.4	12.2	0.35
10/81	10	1,450	5.8	500	7.2	1.5	Gr	0.5	10.7	0.38

1/ Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Si = Silt

2/ Not available

Table 4-3. Physical and Chemical Characteristics at Station YC-1 for 1981 RBOSC MDP Study

	PARAMETERS									
Date	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth (cm)	Velocity (m/s)
4/81	11	1,950	10.8	570	8.1	1.6	Gr,Si	1.8	7.6	0.25
7/81	25	1,700	7.5	518	8.1	8.4	Gr	0.2	3.7	0.38
10/81	7	1,600	10.8	520	7.8	2.7	Co,Si	0.3	6.1	0.27

1/ Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Si = Silt

Table 4-4. Physical and Chemical Characteristics at Station YC-2 for 1981 RBOSC MDP Study

	PARAMETERS									
Date	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth (cm)	Velocity (m/s)
4/81	14	1,975	12.6	865	8.0	1.1	Gr,Si	0.6	10.2	0.19
7/81	16	1,650	11.2	820	8.3	1.7	Gr	0.6	9.1	0.41
10/81	11	1,980	10.2	770	8.0	7.0	Gr	0.6	12.2	0.21

1/ Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Si = Silt

Table 4-5. Physical and Chemical Characteristics at Station YC-3 for RBOSC MDP Studies (1977-1981) and RBOSC Baseline Studies (1974-1976)

	PARAMETERS									
Date	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth (cm)	Velocity (m/s)
Baseline										
10-11/74	7	3,000	8.7	1,149	8.5	12	Gr	0.70	11.4	0.52
4/75	14	3,700	9.4	1,291	9.6	81	Gr,Si,Sa	0.30	8.9	0.40
7-8/75	19	3,800	8.7	1,375	8.8	7	Sa,Si	1.4	91.4	0.43
10/75	11	3,850	10.6	1,485	8.7	13	Gr,Sa	1.0	7.6	0.40
4/76	19	4,000	9.4	1,632	8.7	110	Gr	1.5	10.2	0.34
7-8/76	31	4,500	8.6	1,664	8.0	3	Gr,Sa	0.24	7.6	0.34
MDP										
10/77	11	4,100	7.1	1,658	8.6	NA[2/]	Gr,Sa	0.55	1.8	0.58
4/78	16	4,200	8.2	1,444	8.1	75	Co,Gr	0.91	10.2	0.46
7/78	23	5,000	7.4	2,700	8.9	NA	Gr,Sa	0.30	12.7	0.43
10/78	11	5,000	7.4	1,732	8.6	2	Gr,Si	1.7	8.9	0.27
4/79	22	2,500	8.7	1,544	8.3	120.0	Gr,Sa	2.0	12.7	0.40
7/79	18	3,650	5.8	1,476	8.7	2.0	Gr	2.0	10.2	0.46
10/79	8	3,050	9.0	1,140	8.2	15.0	Gr,Si	2.8	10.2	0.37
4/80	8	3,445	10.0	1,355	8.5	78.5	Sa,Co,Si	3.1	6.9	0.25
10/80	12	3,050	13.0	1,190	8.8	640	Sa,Co,Si	1.5	11.6	0.57
4/81	10	3,400	10.4	1,390	8.3	7.2	Gr,Si	0.7	7.8	0.42
7/81	26	3,250	8.4	1,390	8.9	11	Gr,Si	0.8	25.9	0.35
10/81	10	2,400	7.9	1,510	8.2	38	Gr,Si	0.6	30.5	0.30

1/ Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Si = Silt

2/ Not available

Table 4-6. Physical and Chemical Characteristics at Station WR-1 for RBOSC MDP Studies (1977-1981) and RBOSC Baseline Studies (1974-1976)

Date	Water Temp. (°C)	Conductivity (μmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (m)	Depth[3] (cm)	Velocity[3] (m/s)
				PARAMETERS						
Baseline										
10-11/74	11	630	12.1	199	8.6	7	Co	13.7	5.1,48.3,35.6	0.12,0.12,0.18
4/75	15	850	9.8	207	8.5	44	Gr,Si	14.2	5.1,58.4,10.2	0.12,N/A[2],0.37
7-8/75	18	625	8.5	473	8.2	28	Sa,Si	13.7	20.3,71.1,45.7	0.12,N/A,0.37
10/75	9	725	11.1	186	8.3	9	Co,Gr	15.2	25.4,55.9,55.9	0.06,N/A,0.30
4/76	17	645	10.6	188	8.4	32	Co	15.5	10.2,55.9,20.3	0.37,0.30,0.21
7-8/76	20	935	7.3	256	8.0	250	Co,Si	14.0	55.9,55.9,45.7	0.21,0.24,0.12
MDP										
10/77	9	900	9.6	214	8.3	59.0	Co	11.9	2.5,25.4, N/A	0.24,0.34,N/A
4/78	9	700	9.6	184	8.2	89.0	Co,Si	15.5	20.3,25.4,10.2	0.37,0.58,0.43
7/78	21	670	7.9	180	8.7	6.0	Co,Si	18.3	20.3 25.4,20.3	0.64,0.76,0.52
10/78	7	800	10.3	178	8.0	0.9	Co,Si	15.8	15.4,35.6,10.2	N/A,0.43,N/A
4/79	20	450	7.7	162	8.4	18.0	Gr	16.6	35.6,38.1,45.7	0.58,0.61,0.30
7/79	20	450	7.7	162	8.4	18.0	Gr	16.5	66.0,27.9,22.9	0.64,0.64,0.34
10/79	9	725	8.2	180	7.9	14.0	Sa,Si,Gr	15.5	25.4,43,2,71.1	0.15,0.12,0.49
4/80	11	620	8.0	160	8.2	575	Co,Si	17.1	30.5,45.7,22.9	1.2,1.1,0.7
7/80	20	710	8.8	240	8.3	9.0	Co,Si	13.9	30.5,24.4,17.4	0.52,0.46,0.41
10/80	8	695	10.3	205	7.8	NA	Sa,Co,Si	14.3	50.6,51.2,20.7	0.65,0.66,0.43
4/81	12	390	8.8	153	7.7	44	Co,Si	16.5	42.7,36.6,21.3	0.74,0.76,0.48
7/81	22	630	9.3	210	8.5	29	Co	13.1	22.9,22.9,15.2	0.54,0.39,0.24
10/81	11	700	8.5	200	8.1	33	Co,Si	13.4	30.5,18.3,15.2	0.39,0.54,0.12

1/ Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Si = Silt

2/ Not available

3/ Measured at the left, middle, and right sections of the river

Table 4-7. Physical and Chemical Characteristics at Station WR-2 for RBOSC MDP Studies (1977-1981) and RBOSC Baseline Studies (1974-1976)

Date	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1/]	Width (m)	Depth[3/] (cm)	Velocity[3/] (m/s)
				PARAMETERS						
Baseline										
10-11/74	11	765	10.8	224	8.7	8	Co,Si	6.9	2.5,30.5,5.1	1.0,N/A[2/],0.70
4/75	13	850	10.1	107	8.4	53	Gr,De	6.3	2.5,27.9,2.5	0.58,N/A,1.1
7-8/75	18	685	8.2	453	8.2	20	Co,Gr	10.7	17.8,40.6,15.2	0.64,N/A,0.94
10/75	9	780	10.9	192	8.3	9	Co,Gr	7.9	22.9,33.0,20.3	1.4,1.4,0.55
4/76	11	895	10.5	186	8.4	43	Gr,Sa	7.6	10.2,30.5,5.1	0.85,1.2,0.58
7-8/76	20	985	7.4	278	8.0	365	Co	7.3	20.3,27.9,12.7	0.37,0.98,0.76
MDP										
10/77	9	1,050	9.7	269	8.1	67.0	Co	7.9	5.1,N/A,20.3	0.37,N/A,0.70
4/78	9	700	9.6	184	8.2	95.0	Co,Si	15.5	20.3,25.4,10.2	0.37,0.58,0.43
7/78	21	705	7.5	183	8.7	8.0	Co,Gr	6.7	20.3,30.5,15.2	0.61,1.0,0.70
10/78	7	780	10.2	170	8.0	1.0	Co	10.7	17.8,38.1,22.9	0.24,0.18,0.21
4/79	12	735	9.5	179	7.5	103.0	Gr	12.6	25.4,17.9,35.6	0.70,1.1,0.64
7/79	19	500	7.6	164	8.7	19.0	Gr	11.2	25.4,43.2,48.3	0.88,0.85,0.79
10/79	9	825	8.0	178	7.9	20.5	Sa,Gr	8.1	17.8,25.4,30.5	0.67,0.61,0.88
4/80	11	1,200	8.1	341	8.4	725	Gr,Sa,Co	10.2	30.5,51.2,45.7	1.3,1.1,1.2
7/80	19	820	8.4	285	8.3	8.5	Sa,Co	9.2	13.7,28.7,21.9	0.69,0.74,0.67
10/80	8	835	10.2	175	7.8	NA	Co,Si	11.0	51.7,39.0,22.6	0.83,0.84,0.93
4/81	11	530	8.9	173	7.7	47	Co,Si	17.7	54,9,36.6,24.4	0.69,0.71,0.49
7/81	22	860	9.9	203	8.4	19	Co	15.0	38.1,30.5,27.4	0.21,0.12,0.10
10/81	11	850	7.8	680	8.1	34	Co	14.9	41.1,30.5,24.4	0.38,0.21,0.25

1/ Substrate abbreviations: Gr = Gravel; Sa = Sand; De = Detritus; Co = Cobble; Si = Silt

2/ Not available

3/ Measured at the left, middle, and right sections of the river

In addition to the hydraulic parameters reported in Tables 4-2 to 4-7, stream discharge measurements were taken at each station (Table 4-8). These measurements permit the evaluation of flow on the aquatic ecosystem and make it possible to calculate the net impact of various sources on water quality. For instance, by measuring the flow and water quality of lower Yellow Creek and the White River near the Yellow Creek confluence, it is possible to estimate the net effect of Yellow Creek inflow on the White River.

All stations generally display a definite spring run-off peak and the lowest discharges generally occur in the summer. A notable exception to this in 1981 was Corral Gulch, which displayed a peak discharge in July. Yellow Creek at Stations YC-1 and YC-2 almost dries up completely during the summer.

B. Water Quality Measurements

1. Objectives and Rationale

Water quality strongly influences the many potential uses of flowing water systems and the distribution and abundance of the biota inhabiting them. Any change in stream water quality resulting from RBOSC project activities must be quickly and adequately detected by the MDP aquatic and hydrology monitoring programs. Measurements of selected chemical parameters at stations on Corral Gulch, Yellow Creek, and the White River allow for the examination of change in water quality downstream of Tract C-a.

2. Methods

The methods used to collect and analyze water quality samples are described in RBOSC MDP Monitoring Report 1 (RBOSC 1978).

Table 4-8. Stream Discharge Data for RBOSC MDP Aquatic Monitoring Study, 1981

STATION	Discharge (m^3/s)		
	April	July	October
CG-1	0.020	0.033	0.025
YC-1	0.017	0.0042	0.011
YC-2	0.015	0.0040	0.014
YC-3	0.045	0.046	0.048
WR-1	3.4	0.81	0.91
WR-2	3.4	0.86	0.96

3. Results and Discussion

Station YC-1 on Yellow Creek contains generally higher concentrations of dissolved solids than the upstream Station CG-1, (Appendix 4-1). Such a downstream accumulation in dissolved load is typical of streams in the arid regions of the Southwest and is probably attributable to inflows of saline groundwaters.

Stations YC-1 and YC-2 were first sampled in 1981. Station YC-1 is located at the headwaters of Yellow Creek near the confluence of Corral Gulch and Stake Spring Draw (Figure 4-1). Further downstream, Yellow Creek flows beneath the surface of the alluvial channel. Station YC-2 is located just below the point where the stream emerges from the alluvium. Large differences in the water quality parameters between these two stations are shown by the data presented in Appendix 4-1. Total dissolved solids (TDS), total alkalinity, sodium, magnesium, and sulfate were consistently higher at Station YC-2 than at Station YC-1, while calcium concentrations were consistently lower. Between Stations YC-2 and YC-3, the most downstream station on Yellow Creek, TDS again increased substantially. The measured values for TDS, total alkalinity, and sodium increased, while magnesium and sulfate levels decreased between Stations YC-2 and YC-3. This overall downstream increase in the dissolved load of Yellow Creek is likely due to inputs of significant amounts of ground water with relatively high salt content along the stream course.

No changes in the water quality data were apparent for the White River Stations WR-1 and WR-2 during 1981 except for an apparently marked increase in TDS at WR-2 in October. This increase was not noted at the upstream station, WR-1. The increase in TDS at Station WR-2 was probably due to sampling error rather than to contributions by Yellow Creek. Calculation of net loading for the October 1981 sampling period indicate that TDS would only increase by approximately 100 mg/l at Station WR-2 compared to WR-1 due to the inflow from Yellow Creek.

4.2 BIOTIC COMPONENTS

A. Periphyton

1. Objectives and Rationale

The sensitivity of periphyton to changes in their environment has been well documented (Cholnoky 1968; Round 1973; Lowe 1974; Hutchinson 1975; Whitton 1975; Patrick 1977). Periphyton communities are amenable to sampling techniques which produce a good data base for identifying short-term, acute changes. Species composition, relative abundance, and diversity are reported for the 1981 sampling season.

2. Methods

The methods used for the identification and enumeration of the periphyton are described in MDP Report 5 (RBOSC 1980). The program has been modified somewhat in that the analysis of periphyton biomass has been discontinued and the number of samples collected has been changed. Under the revised montoring program, six replicate samples were collected from each station during 1981 in order to enhance the statistical comparability of the data. Previously, the number of samples collected varied from station to station.

3. Results and Discussion

A total of 160 taxa was identified from the periphyton samples collected during the Aquatic Studies portion of the 1981 MDP Monitoring Program. Species composition among stations for all sampling periods is provided in Appendix 4-2.1. Seasonal changes in species occurrence at each station are presented in Appendix 4-2.2. Periphyton enumeration data for 1981 are provided in Appendix 4-2.3. Appendix 4-2.4 lists the periphyton density and species diversity estimates by sampling date for all stations surveyed during 1981. The results of statistical analyses performed on the periphyton data are presented in Appendix 4-2.5. The mean densities of dominant taxa

(comprising ≥1% of the total density) collected during the RBOSC aquatic baseline studies (1974-1976) and MDP monitoring studies (1978-1981) are presented in Table 4-9 by station and sampling date. A comparison of species diversity for periphyton samples collected during baseline and MDP studies is provided in Table 4-10.

Periphyton community structure is influenced by factors such as climate, light, temperature, current velocity, substrate, turbidity and water chemistry. The strength of the current and the water chemistry are two of the most important factors influencing the kinds of species present in a stream (Lowe 1974; Patrick 1977). Sudden increases in stream flow and heavy spring runoff can affect periphyton densities by producing short-term, effect-specific changes in the community structure.

Total periphyton density was analyzed using a three-way analysis of variance. Mean differences in density between 1979, 1980, and 1981, the three sampling seasons, and the six sampling stations were tested for statistical significance. Interactions between classifications were also included in the analysis. Mean differences in periphyton densities among stations and seasons for 1981 were tested with a two-way analysis of variance, and mean densities between seasons within 1981 at each station were tested with a one-way analysis of variance.

The 1981 periphyton densities proved to be significantly greater than 1980 or 1979 values (Table 4-11). Over the past three years, the fall densities were distinctly higher than spring algal abundances. In addition, there was a significant three-way interaction between year, season, and station classifications. The two-way interaction between year and station was also significant. However, no differences were noted between sampling stations.

The two-way analysis showed no significant differences between sampling station location or season for 1981 alone (Table 4-12). Similarily, one-way analyses showed no seasonal differences in periphyton numbers within any of the six sampling stations in 1981 (Table 4-13).

Table 4-9. Mean Densities of the Most Abundant Algal Species (>1% of Total Density) in Periphyton During RBOSC MDP Studies (1978-1981) and RBOSC Aquatic Baseline Studies (1974-1976)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	1975	1976	MDP 1978	1979	1980	1981
STATION CG-1	APRIL							
Achnanthes lanceolata	1/		288	..	..	..	26	110
A. minutissima			..	..	..	..	31	74
A. spp.			4,481	14,765	94	905	..	..
Batrachospermum sp.			..	..	..	..	..	..
Bicoeca lacustris			..	631	162	..	..	..
Fragilaria vaucheriae			..	..	..	364	41	201
Gomphonema intricatum			..	12,929	..	..	..	..
G. olivaceum			..	..	..	..	..	22
Meridion circulare			..	3,240	..	..	5	..
Navicula arvensis			..	..	25	..	..	..
N. cryptocephala vars.			830	2,081	14	..	3	8
N. pelliculosa			..	15,230	..	..	2	..
N. secreta var. apiculata			..	..	..	..	17	74
N. viridula			..	..	..	..	70	..
Nitzschia capitellata			..	..	1,008	23	..	..
N. frustulum			125	..	..	..	3	..
N. holsatica			..	..	..	..	..	101
N. linearis			..	..	..	..	..	21
Phormidium spp.			..	..	..	3,148	61	..
Surirella ovata			..	..	..	..	25	..
Synedra minuscula			..	..	..	78	..	..
	JULY							
Achnanthes affinis	1/		..	..	..	..	567	644
A. lanceolata var. dubia			..	..	..	..	..	56
A. spp.			835	10,784	86	5,816	..	..
Biocoeca lacustris			..	600	..	..	..	..
Calothrix sp.			..	..	..	..	21	..
Cymbella affinis			..	4,420	..	..	..	..
C. minuta var. silesiaca			..	..	..	..	..	18
C. minutesta			..	..	..	..	47	..
Diatoma tenus var. elongatum			..	..	..	..	17	..
Fragilaria crotonensis			..	..	..	..	63	..
F. vaucheriae			80	708	..	203	201	..
Gomphonema intricatum			79	805	..	..	..	..
Navicula arvensis			28	402	..	..	1	..
N. cryptocephala			192	3,162	2	..	..	..
N. c. var. veneta			..	..	..	..	..	32
N. halophila			..	..	..	19	..	

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
STATION CG-1	JULY cont.							
N. pelliculosa			172	..	..	..	1	20
N. secreta var. apiculta			..	..	..	..	62	30
N. viridula			..	538	..	..	..	..
Nitzschia capitellatau			70	1,377	..	..	..	..
N. dissipata			..	..	..	..	..	27
N. frustulum			43	362	61	..	6	712
N. holsatica			57	..	..	..	..	..
N. latens			..	187	5	..	..	..
N. palea			55	..	..	..	..	..
Rhopalodia musculus			..	..	..	..	..	28
Surirella ovata			11	958	..	..	5	..
Synedra sp.			..	..	..	..	74	..
	OCTOBER							
Achnanthes affinis		..	..	1/	..	..	..	23
A. lanceolata		653	1,689		158	..	2	..
A. lanceolata var. dubia		..	..		..	..	..	277
A. minutissima		..	..		..	..	227	..
A. spp.		5,378	11,312		3,864	14,889	..	..
Batrachospermum sp.		..	..		..	..	142	..
Biocoeca lacustris		..	3,289		..	..	..	..
Cladophora sp.		..	..		..	..	..	36
Cymbella affinis		..	290		..	..	..	..
Gomphonema intricatum		428	1,632		669	..	..	..
Lyngbya spp.		956	124		930	..	..	..
Meridion circulare		281	..		..	..	..	..
Navicula arvensis		281	769		..	..	..	..
N. cryptocephala		7,223	2,949		862	..	..	..
N. cryptocephala var. veneta		..	..		..	..	..	24
N. heufleri		..	..		..	..	7	..
N. pelliculosa		..	388		1,521	..	..	..
N. secreta var. apiculata		..	..		..	..	20	275
N. viridula		..	75		744	..	..	..
N. v. var. avenacea		..	..		..	..	26	..
Nitzschia acicularis		79	2,110		..	..	1	..
N. capitellata		..	84		490	..	..	..
N. frustulum		158	68		213	..	9	772
N. linearis		214	25		..	..	..	..
N. palea		281	606		177	..	1	34
Phormidium spp.		..	..		..	246	..	242
Plectonema sp.		..	..		518	..	..	..
Surirella ovata		..	90		508	..	1	..

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	1975	1976	MDP 1978	1979	1980	1981
STATION YC-1[2/]	APRIL							
Acnanthes affinis								6,949
A. lanceolata								622
A. minutissima								184
Cocconeis placentula								152
Cyclotella maneghiniana								1,169
Cymbella minuta								194
Diatoma tenue var. elongatum								430
Enteromorpha sp.								2,472
Fragilaria vaucheriae								1,251
Navicula secreta var. apiculata								236
Nitzschia frustulum								271
Synedra minuscula								236
	JULY							
Achnanthes affinis								119
A. lanceolata var. dubia								111
A. minutissima								76
Cyclotella meneghiniana								27
Navicula cryptocephala var. veneta								102
N. heufleri								29
N. notha								19
N. pelliculosa								135
N. secreta var. apiculata								94
Nitzschia frustulum								925
	OCTOBER							
Achnanthes affinis								1,019
Bulbochaeta								1,065
Cyclotella meneghiniana								80
Gomphonema angustatum								113
Navicula notha								61
Nitzschia frustulum								1,561
Rhopalodia musculus								88
STATION YC-2[2/]	APRIL							
Achnanthes minutissima								318
Anabaena sp.								388
Bulbochaeta sp.								5,272
Fragilaria capucina								132

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	1975	1976	MDP 1978	1979	1980	1981
STATION YC-2[2/]	APRIL cont.							
Navicula halophila								80
Nitzschia frustulum								341
N. holsatica								442
Rhopalodia gibba								543
R. musculus								188
	JULY							
Achnanthes affinis								702
A. hauckiana var. rostrata								251
Bulbochaeta sp.								1,675
Cladophora sp.								114
Nitzschia frustulum								3,118
Stigeoclonium tenue								1,185
Synedra pulchella var. lanceolata								176
	OCTOBER							
Achnanthes affinis								245
A. hauckiana var. rostrata								585
Bulbochaeta sp.								6,357
Nitzschia frustulum								1,546
Rhopalodia gibba								220
STATION YC-3	APRIL							
Achnanthes affinis	[1/]	..	..	..	..	..	2,538	
Achnanthes lanceolata		..	..	..	..	4	..	
A. minutissima		..	..	..	..	22	..	
A. spp.		1,337	6	6,226	..	..	..	
Bulbochaeta sp.		..	..	..	..	..	1,467	
Cyclotella meneghiniana		..	..	..	..	..	90	
Cymbella affinis		72	..	..	..	..	..	
C. minuta var. silesiaca		..	..	..	..	..	301	
Diatoma hiemale		..	..	..	..	3	..	
Fragilaria capucina		..	..	..	..	19	..	
F. vaucheriae		108	48	10	262	35	..	
Gomphonema olivaceum		13	9	..	35	1	..	
Navicula cryptocephala		..	..	..	..	4	..	
N. cryptocephala var. veneta		..	..	..	..	3	..	
N. pelliculosa		518	1,334	21,965	729	24	..	
N. secreta var. apiculata		..	..	..	..	8	..	
Nitzschia capitellate		..	190	3	..	..	..	

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
STATION YC-3	APRIL cont.							
N. fonticola			..	..	..	232	2	..
N. frustulum			32	18	1,635	..	1	..
N. holsatica			..	80	..	475	16	..
N. microcephala			..	..	355	..	..	..
N. palea			45	84	909	..	9	..
N. spp.			..	..	..	29	..	..
Surirella ovata			243	1,035	52	280	68	212
Synedra amphicephala			9	1,350	2	..	..	..
S. minuscula			..	..	..	26	..	..
S. pulchella var. lanceolata			..	..	..	..	..	148
sulfur bacterium			..	..	..	..	2,637	..
	JULY							
Achnanthes affinis		1/	..	..	..	..	866	579
A. spp.			84	36	86	..	13	..
Bulbochaeta spp.			..	..	..	72	1,583	3,448
Calothrix spp.			2	177	2,117	..	..	..
Cladophora spp.			2	25	..	..	491	..
Cyclotella meneghiniana			24	162	18	15	443	..
Cymbella pusilla			..	21	13	..	..	..
C. ventricosa			24	3	..	..	..	..
Gomphonema olivaceum			25	..	..	..	..	..
Mastogloia elliptica			..	71	2	3	..	..
Navicula cryptocepha			111	36	2	..	..	..
N. pelliculosa			122	..	..	..	..	..
N. viridula			35	99	..	..	4	56
Nitzschia fonticola			128	9	..	22	..	..
N. frustulum			64	747	61	..	11	224
N. holsatica			32	111	..	2	..	..
N. latens			..	38	5	..	..	..
N. microcephala			3	15	22	..	..	..
Rhopalodia musculus			..	..	..	..	..	151
Synedra pulchella			..	..	..	4	..	..
S. pulchella var. lanceolata			..	..	..	..	344	..
unidentified pennate diatoms			..	..	..	1	..	..
sulfur bacterium			..	..	..	..	757	..
	OCTOBER							
Achnanthes affinis		..	..	1/	..	..	2,927	435
A. spp.		7,718	7,629		49	478	..	..
Bulbochaeta sp.		..	..		..	..	1,094	4,011

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
STATION YC-3	OCTOBER cont.							
Calothrix spp.		2,059	..		..	..	..	..
Cyclotella meneghiniana		855	60		117	..	103	83
Cymbella affinis		7,830	..		..	..	..	..
C. minuta var. silesiaca		..	..		..	..	74	..
C. pusilla		23	330		3	..	..	..
Navicula cryptocephala		214	131		6	..	..	..
N. viridula		..	30		119	..	..	..
N. sp. #1		..	8		74	..	..	170
Nitzschia frustulum		124	356		295	..	52	558
N. holsatica		..	..		41	..	..	..
N. latens		..	27		183	..	..	77
N. linearis		..	..		..	..	..	136
N. microcephala		..	4		97	..	..	..
N. palea		45	203		33	..	..	..
Rhopalodia musculus		..	..		..	..	..	876
Surirella ovata		..	..		43	..	9	..
Synedra pulchella var. lanceolata		..	..		..	..	..	540
Thalassiosira fluviatilis		..	4		73	..	..	..
STATION WR-1	APRIL							
Achnanthes minutissima		1/	..	..	..	..	50	327
A. spp.			202	102	22	40	..	..
Amphora ovalis var. pediculus			360	1,632	8	..	..	..
Calothrix spp.			124	1,020	..	..	..	..
Cladophora sp.			..	..	..	..	..	3,399
Cymbella minuta			..	..	..	19	5	..
C. m. var. silesiaca			..	..	..	..	..	210
Diatoma vulgare			..	..	..	..	..	200
Epithemia sorex			911	1,371	..	110	252	866
Gomphonema olivaceum			675	634	2,944	292	64	214
Navicula notha			..	..	..	..	..	270
N. pelliculosa			79	..	1,951	35	1	..
N. tripunctata			1,463	816	26	..	2	..
N. viridula			2,014	4,477	402	44	956	2,927
Nitzschia dsipata			1,957	1,519	258	29	168	..
N. fontica			..	..	..	16	4	..
N. fruslulum			168	997	18	15	11	189
N. holsatica			..	..	..	15	..	..
N. palea			..	..	..	..	19	..
Phormidium spp.			..	..	..	143	4	..
Rhoicosphenia curvata			..	..	..	19	27	2,333
Surirella ovata			540	57	18	..	21	..

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	1975	1976	MDP 1978	1979	1980	1981
STATION WR-1	JULY							
Achnanthes minutissima		1/	..	..	..	..	197	107
A. spp.			30	45	180	17	..	..
Amphora ovalis var. pediculus			365	5,269	569	..	..	..
A. perpusilla			..	..	..	42	69	..
Audouinella violacea			..	..	..	..	193	141
Biocoeca lacustris			233	..	..	..	..	..
Calothrix spp.			30	3,241	2,994	14	..	..
Cladophora glomerata			..	..	..	..	1,825	..
C. sp.			..	..	..	..	..	3,703
Cocconeis pediculus			..	..	..	..	..	1,161
C. placentula			..	..	..	..	140	292
Cymbella affinis			52	..	114	..	..	..
C. minuta			..	..	..	..	16	29
C. minuta var. silesiaca			..	..	..	..	141	..
C. sinuata			45	87	146	..	12	..
Diatoma vulgare			270	..	..	18	654	..
Epithemia sorex			60	742	297	..	1,848	2,054
Fragilaria vaucheriae			..	..	..	..	70	..
Gomphonema olivaceum			..	..	..	12	..	..
Lyngbya spp.			2,208	..	1,385	332	..	..
Navicula arvensis			..	..	..	12	..	..
N. cryptocephala			907	373	111	63	45	..
N. cryptocephala var. veneta			..	..	..	..	74	..
N. notha			..	..	..	..	..	166
N. pelliculosa			..	..	..	37	..	..
N. salinarum var. intermedia			89	15	106	11	..	..
N. tripunctata			217	219	31	20	19	..
N. tripunctata var. schizonemo			..	..	..	..	..	101
N. viridula			..	..	..	..	272	170
N. viridula var. avenacea			..	..	..	..	125	100
Nitzschia chasei			142	98	..	..	..	..
N. dissipata			232	94	160	..	70	..
N. fonticola			..	..	..	50	..	..
N. frustulum			157	117	195	..	132	162
N. holsatica			352	..	50	29	12	..
Phormidium sp.			..	..	..	..	..	162
Rhoicosphenia curvata			..	..	..	12	400	283
Synedra ulna			502	..	8	77	101	..
unidentified pennate diatoms			..	..	..	..	97	..

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
STATION WR-1	OCTOBER							
Achnanthes minutissima		..	..	1/	..	..	..	404
A. spp.		34	169		62	91	..	..
Amphora ovalis var. pediculus		23	495		6	..	..	..
A. perpusilla		..	..		..	20	1	..
Anabaena sp.		..	..		..	..	64	..
Calothrix spp.		1,103	124		..	141	..	..
Cladophora glomerata		..	..		..	..	225	..
C. sp.		..	..		..	..	..	6,813
Cocconeis pediculus		168	23		16	20	113	2,974
C. placentula		..	..		..	21	6	419
Cymbella affinis		..	..		..	15	..	..
C. minuta var. silesiaca		..	..		..	..	74	..
C. sinuata		..	..		15	..	..	..
Diatoma vulgare		..	..		..	..	62	..
Epithemia sorex		5,411	7,594		..	460	1,590	2,288
Gomphonema intricatum		22	113		24	..	..	..
G. olivaceum		259	79		46	..	64	..
G. tenellum		..	..		..	30	..	..
Lyngbya spp.		596	1,317		..	192	..	..
Navicula cryptocephala		259	1,969		..	17	..	..
N. cryptocephala var. veneta		..	..		..	..	34	..
N. pelliculosa		..	..		23	..	..	..
N. salinarum var. intermedium		315	776		..	67	..	..
N. secreta var. apiculata		..	..		..	..	32	..
N. tripunctata		113	787		..	21	63	..
N. viridula var. avenacea		..	..		..	..	90	328
Nitzschia chasei		..	405		..	..	..	..
N. dissipata		146	2,025		6	..	101	..
N. fonticola		..	..		..	17	..	..
N. frustulum		90	450		6	..	31	555
N. holsatica		..	..		8	..	32	..
N. linearis		..	..		..	..	71	..
N. palea		..	..		..	..	68	..
N. spp.		..	..		..	87	32	..
Phormidium sp.		..	..		..	39	56	2,574
Rhoicosphenia curvata		..	..		..	60	139	594
Surirella ovata		..	810		..	..	..	..
unidentified pennate diatoms		..	..		..	30	3	..

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	1975	1976	MDP 1978	1979	1980	1981
STATION WR-2	APRIL							
Achnanthes affinis	1/	..	..	..	..	..	735	
A. lanceolata		..	..	..	3	15	..	
A. minutissima		..	..	..	..	168	6,858	
A. spp.		731	38	22	104	..	..	
Amphora ovalis var. pediculus		79	874	3	..	..	..	
A. perpusilla		..	..	..	3	21	..	
Calothrix spp.		979	7	..	..	..	..	
Cladophora sp.		..	..	..	..	..	2,161	
Cocconeis placentula		..	..	..	2	43	..	
C. minuta var. silesiaca		..	..	..	..	..	722	
Cymbella sinuata		..	180	..	..	64	..	
Epithemia sorex		1,192	117	..	..	283	771	
Fragilaria vaucheriae		..	..	..	5	11	..	
Gomphonema angustatum		..	..	..	..	..	171	
G. olivaceum		574	1,115	1,768	15	137	..	
Lyngbya spp.		259	..	..	..	..	..	
Navicula notha		..	..	..	..	..	177	
N. cryptocephala		889	540	545	2	48	..	
N. pelliculosa		34	82	1,977	28	4	..	
N. tripunctata		292	204	78	..	1	..	
N. viridula		1,204	2,737	560	13	380	2,050	
Nitzschia dissipata		1,474	986	590	..	253	407	
N. fonticola		..	..	..	3	27	..	
N. frustulum		101	187	103	..	3	395	
N. palea		123	243	4	..	43	200	
N. sp.		..	..	..	..	27	..	
Phormidium sp.		..	..	..	..	..	466	
Plectonema spp.		250	..	..	..	..	..	
Rhoicospenia currata		..	..	..	..	..	274	
Surirella ovata		..	..	..	..	13	..	
	JULY							
Achnanthes minutissima	1/	135	45	6	8	392	..	
Amphora ovalis var. pediculus		2,129	306	6	..	..	..	
A. perpusilla		..	..	..	44	91	..	
Audouinella violacea		..	..	..	..	722	..	
Bicoeca lacustris		120	..	18	..	..	..	
Calothrix spp.		52	2,709	58	..	..	..	
Cladophora glomerata		..	..	..	..	1,008	..	
C. spp.		1	33	26	..	..	8,039	

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
STATION WR-2	JULY cont.							
Cocconeis pediculus			..	329	..	..	..	4,190
C. placentula			..	91	22	..	51	..
Cyclotella meneghiniana			..	..	..	3	67	..
Cymbella minuta			..	..	..	5	113	..
C. m. var. silesiaca			..	..	..	..	129	..
C. sinuata			307	170	8	5	6	..
Diatoma vulgare			..	..	..	..	264	..
Epithemia sorex			127	5,315	3	..	1,961	3,165
Fragilaria vaucheriae			143	11	..	4	8	..
Gomphonema intricatum			82	283	..	..	8	..
G. olivaceum			420	34	17	21	140	..
Lyngbya spp.			5,160	..	80	75	..	..
Navicula cryptocephala			398	328	2	22	26	..
N. pelliculosa			..	..	..	7	..	..
N. tripunctata			22	79	..	4	18	..
N. viridula			..	..	..	5	25	..
N. v. var. avenacea			..	..	..	..	129	..
Nitzschia dissipata			306	11	3	..	139	..
N. fonticola			..	..	..	12	..	..
N. frustulum			135	79	22	..	631	336
N. holsatica			239	..	1	17	..	..
N. spp.			..	..	..	..	..	..
Phormidium spp.			..	..	..	22	88	763
Rhiocosphenia curvata			..	..	..	..	198	894
Stigeoclonium tenue			..	..	..	..	714	..
Synedra ulna			..	..	..	..	30	..
	OCTOBER							
Achnanthes minutissima		..	..	1/	..	..	..	151
A. spp.		956	197		197	185	..	..
Amphora ovalis var. pediculus		11	2,043		2	..	..	..
A. perpusilla		..	..		..	13	..	..
Calothrix sp.		..	..		..	..	..	118
Cladophora glomerata		..	..		..	..	934	..
C. sp.		..	..		..	..	..	5,108
Cocconeis pediculus		90	..		2	..	172	1,046
C. placentula		..	..		9	27	10	..
Cymbella affinis		371	57		..	22	..	..
C. minuta var. silesiaca		..	..		..	..	1,434	..
C. sinuata		..	338		10	35	..	..

Table 4-9 (continued)

STATION/Taxa	Month	Mean Density (units/mm^2) Baseline 1974	1975	1976	MDP 1978	1979	1980	1981
STATION WR-2	OCTOBER cont.							
Diatoma vulgare		..	..		..	..	91	..
Epithemia sorex		2,486	13,231		18	194	151	1,050
Gomphonema intricatum		..	6		152	55	..	..
G. olivaceum		158	113		24	..	75	..
Lemanea fucina		..	..		..	..	999	..
Lyngbya spp.		1,170	1,962		13	53	..	..
Mougeotia spp.		..	..		..	..	12	..
Navicula cryptocephala		889	807		4	11	12	..
N. c. var. veneta		..	..		..	..	..	236
N. pelliculosa		..	..		73	20	..	..
N. rhynchocephala		..	..		..	..	..	113
N. salinarum var. intermedia		338	452		1	..	5	..
N. tripunctata		102	198		..	14	60	..
N. viridula var. avenacea		..	..		..	..	192	453
Nitzschia dissipata		371	1,146		8	..	12	..
N. fonticola		..	..		..	35	3	..
N. frustulum		382	587		23	..	324	413
N. holsatica		45	34		18	..	..	..
N. palea		113	28		..	..	..	168
N. spp.		..	..		..	114	22	..
Oscillatoria spp.		799	96		..	..	..	..
Phormidium sp.		..	..		..	..	..	699
Rhoicosphenia curvata		..	..		..	29	340	275
unidentified pennate diatoms		..	..		..	22	8	..

1/ Periphyton not sampled at this station during this period.

2/ Station newly established in 1981.

.. Not present at $\geq$ 1% relative abundance.

Table 4-10. Comparison of Diversity Indices of Periphyton During RBOSC MDP Studies (1978-1981) and RBOSC Aquatic Baseline Studies (1974-1976)

Station	Month	Index	Baseline			MDP			
			1974	1975	1976	1978	1979	1980	1981
CG-1	April	Shannon	..	1.57	2.24	2.27	1.03	2.59	1.69
		Evenness	..	0.40	0.52	0.71	0.33	0.68	0.49
		No. of Species	..	15	20	14	23	44	31
	July	Shannon	..	2.73	2.93	..	0.21	2.22	1.63
		Evenness	..	0.66	0.67	..	0.82	0.60	0.48
		No. of Species	..	18	21		13	40	30
	October	Shannon	2.49	2.66	..	2.77	0.20	1.45	1.67
		Evenness	0.58	0.61	..	0.67	0.09	0.48	0.54
		No. of Species	19	21	..	17	10	20	22
YC-1	April	Shannon	..	..	..	..	..	..	1.95
		Evenness	..	..	..	..	..	..	0.55
		No. of Species	..	..	..	..	..	..	34
	July	Shannon	..	..	..	..	..	..	1.84
		Evenness	..	..	..	..	..	..	0.53
		No. of Species	..	..	..	..	..	..	32
	October	Shannon	..	..	..	..	..	..	1.74
		Evenness	..	..	..	..	..	..	0.48
		No. of Species	..	..	..	..	..	..	38
YC-2	April	Shannon	..	..	..	..	..	..	1.41
		Evenness	..	..	..	..	..	..	0.44
		No. of Species	..	..	..	..	..	..	24
	July	Shannon	..	..	..	..	..	..	1.80
		Evenness	..	..	..	..	..	..	0.52
		No. of Species	..	..	..	..	..	..	31
	October	Shannon	..	..	..	..	..	..	1.32
		Evenness	..	..	..	..	..	..	0.39
		No. of Species	..	..	..	..	..	..	30
YC-3	April	Shannon	..	1.74	2.17	1.22	1.92	2.52	1.39
		Evenness	..	0.46	0.58	0.36	0.57	0.67	0.46
		No. of Species	..	13	15	11	29	42	21

Table 4-10 (continued)

Station	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
YC-3	July	Shannon	..	3.48	2.70	0.74	1.50	1.69	1.19
		Evenness	..	0.76	0.64	0.27	0.43	0.50	0.36
		No. of Species	..	24	19	7	33	29	28
	October	Shannon	1.77	1.28	..	3.25	0.65	1.05	1.78
		Evenness	0.51	0.34	..	0.76	0.22	0.34	0.51
		No. of Species	11	13	..	18	19	22	33
WR-1	April	Shannon	..	1.47	2.36	0.93	2.36	1.78	2.12
		Evenness	..	0.42	0.60	0.27	0.67	0.50	0.58
		No. of Species	..	12	16	11	34	35	41
	July	Shannon	..	3.44	1.89	2.52	2.64	2.46	2.04
		Evenness	..	0.74	0.49	0.57	0.65	0.63	0.55
		No. of Species	..	26	15	22	59	49	42
	October	Shannon	1.87	2.89	..	2.99	2.44	2.32	2.27
		Evenness	0.44	0.61	..	0.79	0.68	0.58	0.58
		No. of Species	18	26	..	14	36	52	49
WR-2	April	Shannon	..	3.25	2.77	2.09	1.77	2.48	2.24
		Evenness	..	0.69	0.63	0.61	0.51	0.65	0.59
		No. of Species	..	27	21	11	32	44	44
	July	Shannon	..	2.72	2.05	2.91	2.67	2.57	1.72
		Evenness	..	0.57	0.52	0.74	0.71	0.69	0.50
		No. of Species	..	26	16	16	43	41	31
	October	Shannon	..	2.65	2.17	2.39	2.61	2.03	2.13
		Evenness	..	0.61	0.47	0.62	0.72	0.56	0.57
		No. of Species	..	20	24	15	38	39	43

.. Periphyton not sampled during these periods.

Table 4-11. Duncan's Multiple Range Tests (α = 0.05) for the Three-Way Analysis of Variance (Year x Season x Station) of Periphyton Densities[1/]

YEAR

Alpha Level = .05 DF = 2259 MS = 267997

Grouping[1/]	Mean	N	Year
A	178.415301	854	1981
B	77.637112	838	1980
B			
B	67.480624	609	1979

SEASON

Alpha Level = .05 DF = 2259 MS = 267997

Grouping[1/]	Mean	N	Season
A	163.005923	529	Fall
A			
B A	110.932182	955	Summer
B			
B	81.214076	817	Spring

STATION

Alpha Level = .05 DF = 2259 MS = 267997

Grouping[1/]	Mean	N	Station
A	178.088578	143	Yellow Creek -1
A			
A	156.832986	384	Corral Gulch - 1
A			
A	145.887446	154	Yellow Creek - 2
A			
A	107.736555	538	White River - 2
A			
A	86.790662	589	White River - 1
A			
A	83.738540	493	Yellow Creek - 3

1/ Means with the same letter are not significantly different

Table 4-12. Duncan's Multiple Range Tests (α = 0.05) for the Two-Way Analysis of Variance (Station x Season) of Periphyton Densities in 1981[1/]

STATION

Alpha Level = .05 DF = 836 MS = 332189

Grouping[1/]	Mean	N	Station
A	260.069444	96	Corral Gulch - 1
A			
A	260.000000	110	Yellow Creek - 3
A			
A	178.088578	143	Yellow Creek - 1
A			
A	175.686275	170	White River - 2
A			
A	152.486188	181	White River - 1
A			
A	145.887446	154	Yellow Creek - 2

SEASON

Alpha Level = .05 DF = 836 MS = 332189

Grouping[1/]	Mean	N	Season
A	189.623865	257	Summer
A			
A	173.684211	304	Spring
A			
A	173.492605	293	Fall

1/ Means with the same letter are not significantly different

Table 4-13. Duncan's Multiple Range Tests (α = 0.05) for the One-Way Analyses of Variance (by season) of 1981 Periphyton Densities

STATION - CORRAL GULCH - 1

Alpha Level = .05 DF = 93 MS = 448656

Grouping[1/]	Mean	N	Season
A	342.424242	22	Fall
A			
A	249.572650	39	Spring
A			
A	220.000000	35	Summer

STATION - YELLOW CREEK - 1

Alpha Level = .05 DF = 140 MS = 356109

Grouping[1/]	Mean	N	Season
A	211.458333	32	Summer
A			
A	171.428571	63	Fall
A			
A	164.583333	48	Spring

STATION - YELLOW CREEK - 2

Alpha Level = .05 DF = 151 MS = 342653

Grouping[1/]	Mean	N	Season
A	222.695035	47	Summer
A			
A	121.794872	52	Fall
A			
A	103.030303	55	Spring

Table 4-13 (continued)

STATION - YELLOW CREEK - 3

Alpha Level = .05 DF = 107 MS = 403581

Grouping[1/]	Mean	N	Season
A	238.235294	34	Fall
A			
A	204.166667	40	Spring
A			
A	159.259259	36	Summer

STATION - WHITE RIVER - 1

Alpha Level = .05 DF = 178 MS = 225923

Grouping[1/]	Mean	N	Season
A	181.420765	61	Spring
A			
A	147.023810	56	Summer
A			
A	129.687500	64	Fall

STATION - WHITE RIVER - 2

Alpha Level = .05 DF = 167 MS = 305338

Grouping[1/]	Mean	N	Season
A	192.810458	51	Summer
A			
A	168.390805	58	Fall
A			
A	168.306011	61	Spring

1/ Means with the same letters are not significantly different

a. Station CG-1 - The dominant diatom genus in the periphyton baseline and MDP monitoring samples collected at Station CG-1 has been Achnanthes (primarily A. minutissima, A. affinis, and A. lanceolata). Other dominant diatoms at this station in 1981 included Fragilaria vaucheriae, Navicula secreta var. apiculata and Nitzschia frustulum. The diatoms which were dominant in 1979, 1980, and 1981 are characteristic of waters with high alkalinity, high dissolved oxygen, and medium organic load where oxidation takes place (Lowe 1974). The diatoms which were dominant at Station CG-1 prior to 1979 are characteristic of a similar environment with a slightly lower organic load (Lowe 1974).

The only non-diatom taxa dominant at Station CG-1 during the MDP aquatic studies were the blue-green alga Phormidium sp. in 1979, 1980, and 1981; Calothrix sp. in July 1978; the green alga Cladophora sp. in 1980 and 1981; and the Chantransia-phase of the red alga Batrachospermum sp. in October 1980, and April and October 1981. Batrachospermum is generally indifferent to water chemistry, requires a swift current (Hynes 1970), and has been associated with springs and spring-fed streams (Ward and Dufford 1979).

At Station CG-1, the Shannon-Weiner diversity indices for 1981 were generally lower than in previous years with the exception of 1979. The number of species was lower than in 1980, but higher than in previous years. These differences in diversity indices can probably be attributed to a very high natural variability in the periphyton community.

b. Station YC-1 - Enteromorpha sp. and Bulbochaeta sp. were the dominant algae at Station YC-1 in April and October 1981, respectively. The former generally develops best in saline conditions (Smith 1950; Hutchinson 1975). The dominant diatoms in the 1981 studies consisted of Achnanthes affinis, A. lanceolata, A. minutissima, Cyclotella meneghiniana, Fragilaria vaucheriae, Cocconeis placentula, Cymbella minuta, Diatoma tenue var. elongatum, Navicula secreta var. apiculata, Nitzschia frustulum, and Synedra minuscula. These diatoms are characteristic of waters with high alkalinity and medium organic load (Lowe 1974; Patrick 1977).

c. Station YC-2 - At Station YC-2, the dominant alga in 1981 was Bulbochaeta sp. Dominant diatoms included Achnanthes minutissima, A. affinis, A. hauckiana var. rostrata, Navicula halophila, Nitzschia frustulum, Rhopaledia gibba, Rhopaledia musculus and Synedra pulchella var. lanceolata. A. hauckiana var. rostrata, the two Rhopalodia species, and S. pulchella var. lanceolata are indicators of waters with high conductivity. The presence of Entomoneis paludosa and Pleurosigma sp. in the 1981 samples at Station YC-2 also indicate hard water with high conductivity (Patrick and Reimer 1966, 1975).

d. Station YC-3 - At Station YC-3, the dominant taxa in April 1981 consisted of Bulbochaeta sp., Achnanthes affinis, Fragilaria capucina, Surirella ovata and Synedra pulchella var. lanceolata. Surirella ovata reportedly develops best at low water temperatures and usually undergoes maximum growth in the spring (Round 1973). Achnanthes affinis and Fragilaria capucina prefer alkaline waters (Patrick and Reimer 1966). The same algae were dominant in the periphyton during the summer and fall of 1981. In addition, Nitzschia frustulum and Rhopalodia musculus became numerically more important in the summer and fall flora. Based on data from the baseline and monitoring studies, the spring and fall periphyton communities at Station YC-3 are dominated by a group of diatoms whose relative abundance varies annually. In addition, the dominance of green algae in the summer has become more pronounced from 1978 through 1981.

At Yellow Creek Station YC-3, total periphyton densities were higher in 1981 than in 1979 and 1980. The highest values have generally occurred in the fall at this station. Comparison of baseline and monitoring diversity indices and numbers of species present at this station shows a very high degree of variability.

e. Stations WR-1 and WR-2 - Cladophora sp. was the dominant alga at Stations WR-1 and WR-2 in 1981. This green alga had not been reported as a dominant organism in the White River flora until the summer and fall of 1980. Cladophora is favored by high light intensities, medium to high nutrient levels, high pH values, and hard to very hard water (Whitton 1970). The den-

sity of this alga increased from spring to fall in the White River during 1981.

The spring diatom flora at both White River Stations WR-1 and WR-2 was dominated by Achnanthes minutissima, Epithemia sorex, Navicula viridula, Nitzschia frustulum, Nitzschia palea, Rhoicosphenia curvata, and Cymbella minuta var. silesiaca. The summer and fall diatom assemblages at these stations were dominated by Epithemia sorex, Navicula viridula, Nitzshia frustulum, Rhoicosphenia curvata, and Cocconeis pediculus. Cocconeis placentula was a dominant member of the flora at Station WR-1 in the summer and fall of 1981. Epithemia sorex, Rhoicosphenia curvata, and the two Cocconeis species are common epiphytes of Cladophora (Whitton 1970). Their densities increased in proportion to the increase in the Cladophora standing crop. The dominant diatoms at both stations are typically found in alkaline, flowing waters which are rich in oxygen (Lowe 1974; Patrick and Reimer 1966, 1975).

Periphyton densities at Stations WR-1 and WR-2 during 1981 were the highest recorded since the initiation of monitoring studies. Differences in total densities, Shannon-Weiner diversity indices, and total number of species observed between the two White River stations during 1981 were small; accordingly, no impact on the White River periphyton community as a result of Yellow Creek discharge is suggested.

In summary, periphyton densities were higher at the sampling stations in 1981 than in 1979 and 1980. Changes in the periphyton communities since the initiation of baseline studies cannot be explained as seasonal variations. Also, changes in physical parameters such as temperature and current velocity are not consistent with changes observed in the structure of the periphyton communities. Other influences, such as climate, may be affecting these communities. At Station CG-1, the 1981 total periphyton densities were higher than in 1980, but were below baseline values. The red alga, Batrachospermum sp., along with various diatoms dominated the spring flora at this station in 1981. However, the spring community at this station in 1979 and 1980 was dominated by blue-green algae. At Station YC-3, total periphyton densities increased in 1981 over 1979 and 1980 values, but were similar to data from

earlier years. The green alga, Bulbochaeta sp., also displayed increasing dominance in the periphyton community during summer and fall 1979, 1980, and 1981. At Stations WR-1 and WR-2, periphyton densities increased in 1981; Cladophora sp. was the dominant alga at both stations.

Generally, the stations with high conductivity values (Stations YC-1, YC-2 and YC-3) showed species compositions better suited to higher salinity levels. The communites found at the stations with less saline water (Stations WR-1 and WR-2) consisted of taxa such as Epithemia sorex, Lemanea fucina, and Audouinella violaceae--species commonly found in lower saline water (Lowe 1974; Hynes 1970).

Increased water discharge has been shown to depress growth and increase the relative abundance of bacteria and green algae (Russell 1979). At Station CG-1, density and biomass values were generally lower and discharge higher during 1980 than in previous years. Green algae became dominant members of the flora of this station during June and August 1980 for the first time since the initiation of RBOSC aquatic studies. Five green algal genera constituted 16% of the dominant algae at Station CG-1 during August 1980. However, in 1981, algal densities increased and green algae never exceeded 2% of the total algal density at this station. This was probably due, at least in part, to the fact that no discharges of mine water to Corral Gulch occurred in 1981.

Since surface flow originating in the area of Tract C-a disappears into the alluvium a short distance downstream from Station YC-1, it is unlikely that any flow resulting from tract activities has reached the White River. Hydrologic tests have shown that Tract C-a surface waters may not reach lower Yellow Creek or the White River (Section 5.0, Hydrology). Thus, changes observed at Stations YC-3, WR-1 and WR-2 are most likely attributable to natural variations in environmental conditions.

B. Benthos

1. Objectives and Rationale

Benthic macroinvertebrates constitute the major component of the secondary trophic level in aquatic ecosystems on and near Tract C-a. Their limited mobility and well-documented susceptibility to physical and chemical changes in their environment make them a very important element of the MDP Monitoring Program (Kolkowitz and Marsson 1909; Hynes 1960; Tarzwell 1965; Cairns and Dickson 1973; Hart and Fuller 1974; Hilsenhoff 1977; Beck 1977; Hubbard and Peters 1978; Harris and Lawrence 1978; Surdick and Gaufin 1978). Data collected on benthos taxonomic composition, relative abundance, and diversity at all sampling stations permit the evaluation of the effects of development activity on benthos, as well as the identification of potential impacts on other components of the aquatic system.

2. Methods

The methods used for the benthos sampling program are described in RBOSC MDP Report 4 (RBOSC 1980).

3. Results and Discussion

Sixty-three taxa were identified from macroinvertebrate samples collected during the 1981 monitoring studies. The taxonomic composition among stations by sampling dates is provided in Appendix 4-2.6. The seasonal changes in taxonomic occurrence at each station are shown in Appendix 4-2.7. Macroinvertebrate enumeration data by sample date for the 1981 monitoring program are presented in Appendix 4-2.8. Density and diversity calculations for all sites by sampling date are provided in Appendix 4-2.9.

The mean densities of the major macroinvertebrate taxa collected during RBOSC baseline studies (1974-1976) and MDP monitoring studies (1978-1981) are presented in Table 4-14. A comparison of species diversity indices from baseline and MDP studies are provided in Table 4-15.

Table 4-14. Major Benthic Macroinvertebrate Taxa Observed During RBOSC MDP Studies (1978-1981) and RBOSC Aquatic Baseline Studies (1974-1976)

STATION/Taxa	Month	Mean Density (organisms/m^2) Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
STATION CG-1	APRIL							
Nematoda		1/	241	24	42	6	0	..
Oligochaeta			18,190	18	150	42	45	19
Ephemeroptera			2,688	139	..	..	..	26
Plecoptera			91	24	..	..	..	13
Coleoptera			..	..	6	..	7	13
Diptera			476	24	12	6	..	38
Chironomidae			10,896	1,961	66	30	1,372	128
	JULY							
Nematoda			..	30	..	..	..	..
Oligochaeta			30	109	6	283	110	..
Ephemeroptera			54	422	..	..	524	19
Plecoptera			..	60	..	..	..	..
Diptera			24	222	6	12	4,816	6
Chironomidae			102	2,819	42	12	414	13
	OCTOBER							
Nematoda		382	..	1/	..	..	..	..
Oligochaeta		14,551	66		1,617	385	149	32
Hirudinea		..	..		..	..	..	26
Amphipoda		..	..		..	..	..	160
Ephemeroptera		5,358	66		12	126	129	6
Plecoptera		753	1,478		72	788	13	..
Diptera		7,063	416		6	150	162	6
Chironomidae		38,373	409		138	54	65	19
STATION YC-1 2/	APRIL							
Nematoda								19
Oligochaeta								536
Ephemeroptera								128
Trichoptera								6
Coleoptera								243
Diptera								1,015
Chironomidae								817

Table 4-14 (continued)

STATION/Taxa	Month	Mean Density (organisms/m^2) Baseline 1974	1975	1976	MDP 1978	1979	1980	1981
STATION YC-1 (cont.)	JULY							
Ephemeroptera								13
Coleoptera								6
Diptera								6
Chironomidae								6
	OCTOBER							
Oligochaeta								141
Amphipoda								13
Ephemeroptera								262
Odonata								26
Trichoptera								26
Lepidoptera								6
Diptera								4,674
Chironomidae								658
STATION YC-2[2/]	APRIL							
Oligochaeta								1,475
Hirudinea								364
Gastropoda								77
Amphipoda								434
Odonata								19
Coleoptera								38
Diptera								275
Chironomidae								45
	JULY							
Oligochaeta								364
Hirudinea								121
Gastropoda								211
Amphipoda								3,940
Ephemeroptera								243
Odonata								64
Coleoptera								32
Diptera								13
Chironomidae								102

Table 4-14 (continued)

STATION/Taxa	Month	Mean Density (organisms/m^2) Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
STATION YC-2 (cont.)	OCTOBER							
Oligochaeta								1,041
Hirudinea								581
Gastropoda								530
Amphipoda								8,103
Ostracoda								6
Ephemeroptera								121
Odonata								51
Trichoptera								6
Coleoptera								109
Diptera								1,086
Chironomidae								530
STATION YC-3	APRIL							
Nematoda		1/	145	253	289	..	..	..
Oligochaeta			884	2,341	222	12	..	38
Odonata			12	..	..	..	..	6
Diptera			4,157	97	3,156	84	13	141
Chironomidae			5,750	1,001	3,322	403	2,227	1,162
	JULY							
Nematoda		1/	151	127	30	..	..	..
Oligochaeta			977	6	..	12	136	523
Ephemeroptera			..	18	..	..	..	45
Odonata			6	42	150	..	..	6
Coleoptera			24	133	60	6	7	13
Diptera			567	2,801	633	2,412	2,686	1,667
Chironomidae			54	1,725	974	289	..	26
	OCTOBER							
Nematoda		..	833	1/	6	..	..	..
Oligochaeta		63	1,955		42	72	..	900
Ephemeroptera		..	1,152		12	..	..	64
Odonata		25	36		6	..	..	300
Coleoptera		6	6		..	6	..	13
Trichoptera		..	..		..	18	162	..
Diptera		144	1,611		651	867	770	58
Chironomidae		1,127	409		1,893	2,004	19	109

Table 4-14 (continued)

STATION/Taxa	Month	Mean Density (individuals/m^2) Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
STATION WR-1	APRIL							
Oligochaeta		1/	477	59	1,129	111	214	1,162
Ephemeroptera			280	1,698	2,527	513	278	498
Plecoptera			13	78	64	13	26	134
Odonata			..	..	..	6	..	6
Coleoptera			..	..	..	..	..	6
Trichoptera			13	85	233	..	65	77
Diptera			..	13	13	..	..	..
Chironomidae			516	555	608	13	13	607
	JULY							
Oligochaeta		1/	40	378	45	7	13	38
Ephemeroptera			..	2,835	433	1,157	757	4,885
Plecoptera			..	..	6	26	..	..
Coleoptera			..	..	..	20	..	..
Trichoptera			..	47	19	312	149	102
Diptera			34	93	96	40	26	..
Chironomidae			..	33	77	247	142	300
	OCTOBER							
Oligochaeta		250	644	1/	52	1,267	252	345
Ephemeroptera		402	1,322		564	507	162	281
Plecoptera		38	143		12	39	7	6
Trichoptera		163	508		162	124	272	613
Diptera		6	46		13	26	20	45
Chironomidae		853	685		6	1,261	3,450	1,175
STATION WR-2	APRIL							
Nematoda		1/	117	20	13	7	..	..
Oligochaeta			1,602	853	648	292	26	568
Ephemeroptera			742	605	480	624	971	600
Plecoptera			91	157	77	52	123	83
Trichoptera			196	14	77	..	680	677
Diptera			85	13	78	..	52	77
Chironomidae			1,331	46	38	20	32	83
	JULY							
Oligochaeta		1/	1,110	1,107	149	20	155	13
Ephemeroptera			20	4,194	1,031	936	1,146	3,104
Plecoptera			..	157	32	20	39	6

Table 4-14 (continued)

STATION/Taxa	Month	Mean Density (organisms/m^2) Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
STATION WR-2	JULY (cont.)							
Trichoptera			..	358	142	33	123	345
Diptera			14	176	1,325	97	58	64
Chironomidae			33	191	115	65	52	447
	OCTOBER							
Nematoda		119	7	1/	6	..	..	..
Oligochaeta		427	371		13	299	201	102
Ephemeroptera		1,165	1,802		928	3,515	272	620
Plecoptera		226	85					
Trichoptera		1,974	527		273	936	3,372	1,622
Diptera		200	27		26	46	155	58
Chironomidae		303	282		..	812	1,288	89

1/ Site not sampled during this period.

2/ Site newly established in 1981.

.. Taxon absent, or present in only minor quantities.

Table 4-15. Comparison of Diversity Indices of Benthic Macroinvertebrates During RBOSC MDP Studies (1978-1981) and RBOSC Aquatic Baseline Studies (1974-1976)

Station	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
CG-1	April	Shannon	..	2.72	2.36	2.47	2.06	1.51	1.71
		Evenness	..	0.61	0.58	0.92	0.94	0.78	0.74
		No. of Taxa	..	22	17	7	9	7	10
	July	Shannon	..	2.51	3.65	0.86	1.02	0.85	1.24
		Evenness	..	0.90	0.78	0.67	0.57	0.37	0.90
		No. of Taxa	..	7	25	2	6	10	4
	October	Shannon	2.79	2.34	..	0.96	1.47	1.85	1.28
		Evenness	0.60	0.59	..	0.35	0.64	0.80	0.62
		No. of Taxa	24	16	..	8	10	8	8
YC-1	April	Shannon	..	..	..	..	..	..	2.06
		Evenness	..	..	..	..	..	..	0.76
		No. of Taxa	..	..	..	..	..	..	15
	July	Shannon	..	..	..	..	..	..	1.33
		Evenness	..	..	..	..	..	..	0.96
		No. of Taxa	..	..	..	..	..	..	4
	October	Shannon	..	..	..	..	..	..	0.92
		Evenness	..	..	..	..	..	..	0.32
		No. of Taxa	..	..	..	..	..	..	17
YC-2	April	Shannon	..	..	..	..	..	..	1.47
		Evenness	..	..	..	..	..	..	0.56
		No. of Taxa	..	..	..	..	..	..	14
	July	Shannon	..	..	..	..	..	..	0.96
		Evenness	..	..	..	..	..	..	0.37
		No. of Taxa	..	..	..	..	..	..	13
	October	Shannon	..	..	..	..	..	..	1.29
		Evenness	..	..	..	..	..	..	0.45
		No. of Taxa	..	..	..	..	..	..	18
YC-3	April	Shannon	..	2.74	2.17	2.65	1.66	1.57	0.79
		Evenness	..	0.69	0.65	0.69	0.86	0.81	0.33
		No. of Taxa	..	16	10	15	8	7	11
	July	Shannon	..	1.74	2.74	3.16	0.82	0.93	0.89
		Evenness	..	0.53	0.67	0.81	0.29	0.52	0.36
		No. of Taxa	..	10	17	15	16	6	14

Table 4-15 (continued)

Station	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979	MDP 1980	MDP 1981
	October	Shannon	..	2.76	2.47	1.41	1.84	0.82	1.50
		Evenness	..	0.74	0.65	0.48	0.68	0.45	0.57
		No. of Taxa	..	14	14	8	15	6	15
WR-1	April	Shannon	..	3.04	2.40	3.35	1.50	1.62	1.69
		Evenness	..	0.79	0.57	0.69	0.65	0.83	0.63
		No. of Taxa	..	17	19	20	10	7	15
	July	Shannon	..	1.72	2.73	3.15	2.31	2.24	0.65
		Evenness	..	0.97	0.66	0.86	0.72	0.85	0.64
		No. of Taxa	..	4	18	9	25	14	15
	October	Shannon	3.61	4.04	..	2.48	2.23	1.59	1.86
		Evenness	0.83	0.83	..	0.73	0.70	0.56	0.64
		No. of Taxa	20	29	..	10	24	17	18
WR-2	April	Shannon	..	3.49	2.94	3.41	1.64	1.43	1.76
		Evenness	..	0.71	0.79	0.89	0.66	0.58	0.65
		No. of Taxa	..	30	14	15	12	12	15
	July	Shannon	..	1.37	3.47	2.58	1.45	1.72	1.56
		Evenness	..	0.53	0.73	0.66	0.54	0.67	0.53
		No. of Taxa	..	7	27	16	15	13	19
	October	Shannon	..	3.41	3.58	2.23	2.25	1.46	2.05
		Evenness	..	0.72	0.73	0.71	0.69	0.54	0.66
		No. of Taxa	..	27	30	9	26	15	22

.. Macroinvertebrates not sampled during these periods.

The statistical analyses of the benthos data were performed in the same manner as were the periphyton analyses. The results of the analyses are summarized in Appendix 4-2.10. The three-way analysis shows that between 1979 and 1981, benthos densities were significantly higher in the fall than in the spring or summer (Table 4-16). Densities at Station YC-2, WR-1, and WR-2 were discernibly higher than at either Station YC-3 or CG-1. Annual variation proved to be insignificant, while the interaction between season and station proved to be significant. The two-way analysis of season by station effects for 1981 and the one-way analyses by season for each station in 1981 all proved to be insignificant (Tables 4-17 and 4-18).

a. Station CG-1 - In 1981, the macroinvertebrate densities at Station CG-1, on Corral Gulch directly below Tract C-a, were consistently lower than those recorded for the same sampling periods in 1980. In April, Chironomidae was the dominant major taxon at Station CG-1, while Ephemeroptera (Baetidae) was dominant in July and Amphipoda (Talitridae) was dominant in October. All of these organisms have high fecundity rates and short life cycles, characteristics that are perhaps largely responsible for their dominance at a station generally subjected to fluctuations in environmental conditions, particularly stream flow.

During July 1981, a severe summer thunderstorm caused flash flood conditions in Corral Gulch and upper Yellow Creek just prior to collection of July samples. This was evident during sampling by the accumulation of debris and the dampness of the bank above waterline. Substrate scouring from the flood caused decreases in diversity and the number of taxa at this station during July, and the effects apparently persisted through October.

In July 1980, simuliids accounted for most of the high macroinvertebrate densities at Station CG-1. In 1981, however, no members of the family Simuliidae were collected throughout the entire sampling season at this station. Simuliids tend to inhabit areas of swift flow (Merritt and Cummins 1978). Thus, even though the macroinvertebrate community at Station CG-1 may have been affected by flash flooding in July and increased stream flows in July

Table 4-16. Duncan's Multiple Range Tests(α = 0.05) for the Three-Way Analysis of Variance (Year x Season x Station) of Macroinvertebrate Densities[1/]

YEAR

Alpha Level = .05 DF = 1162 MS = 432711

Grouping[1/]	Mean	N	Year
A	218.658470	244	1981
A			
A	206.644375	480	1979
A			
A	181.552708	480	1980

SEASON

Alpha Level = .05 DF = 1162 MS = 432711

Grouping[1/]	Mean	N	Season
A	319.043137	289	Fall
B	190.217916	547	Summer
B			
B	118.028804	368	Spring

STATION

Alpha Level = .05 DF = 1162 MS = 432711

Grouping[1/]	Mean	N	Station
A	442.695556	45	Yellow Creek - 2
A			
A	307.202778	240	White River - 1
A			
A	306.387903	248	White River - 2
B A	238.219444	36	Yellow Creek - 1
B			
B	120.349333	325	Yellow Creek - 3
B			
B	72.140860	310	Corral Gulch - 1

1/ Means with the same letter are not significantly different

Table 4-17. Duncan's Multiple Range Tests ($\alpha = 0.05$) for the Two-Way Analysis of Variance (Station x Season) of Macroinvertebrate Densities in 1981[1/]

STATION

Alpha Level = .05 DF = 226 MS = 576535

Grouping[1/]	Mean	N	Station
A	442.695556	45	Yellow Creek - 2
A			
A	238.219444	36	Yellow Creek - 1
A			
A	215.803472	48	White River - 1
A			
A	157.575000	56	White River - 2
A			
A	139.206306	37	Yellow Creek - 3
A			
A	23.730303	22	Corral Gulch - 1

SEASON

Alpha Level = .05 DF = 226 MS = 576535

Grouping[1/]	Mean	N	Season
A	256.635739	97	Fall
A			
A	250.865672	67	Summer
A			
A	145.637500	80	Spring

1/ Means with the same letter are not significantly different

Table 4-18. Duncan's Multiple Range Tests (α = 0.05) for the One-Way Analyses of Variance (by Season) of 1981 Macroinvertebrate Densities[1/]

STATION - CORRAL GULCH - 1

Alpha Level = .05 DF = 19 MS = 1591.46

Grouping[1/]	Mean	N	Season
A	31.037500	8	Fall
A			
A	23.556667	10	Spring
A			
A	9.550000	4	Summer

STATION - YELLOW CREEK - 1

Alpha Level = .05 DF = 33 MS = 615567

Grouping[1/]	Mean	N	Season
A	340.429412	17	Fall
A			
A	183.784444	15	Spring
A			
A	7.958333	4	Summer

STATION - YELLOW CREEK - 2

Alpha Level = .05 DF = 42 MS = 1805540

Grouping[1/]	Mean	N	Season
A	673.805556	18	Fall
A			
A	390.325641	13	Summer
A			
A	194.183333	14	Spring

Table 4-18 (continued)

STATION - YELLOW CREEK - 3

Alpha Level = .05 DF = 34 MS = 127760

Grouping[1/]	Mean	N	Season
A	195.244444	12	Summer
A			
A	123.281818	11	Spring
A			
A	103.685714	14	Fall

STATION - WHITE RIVER - 1

Alpha Level = .05 DF = 45 MS = 492366

Grouping[1/]	Mean	N	Season
A	354.835556	15	Summer
A			
A	165.95778	15	Spring
A			
A	141.481481	18	Fall

STATION - WHITE RIVER - 2

Alpha Level = .05 DF = 53 MS = 143771

Grouping[1/]	Mean	N	Season
A	210.435088	19	Summer
A			
A	139.642222	15	Spring
A			
A	124.150000	22	Fall

1/ Means with the same letter are not significantly different

and October, the absence of Simuliidae in 1981 at this station reflects a relative decrease in discharge levels in 1981 as compared to previous years.

b. Station YC-1 - Station YC-1 was sampled in 1981 for the first time. Although this station appears to support a larger number of fauna than Station CG-1, the seasonal changes at this site were quite similar to those that occurred in Corral Gulch.

In April, Station YC-1 supported a relatively healthy fauna dominated by Diptera, particularly the Simuliidae and Empididae. The July sample was dominated by baetid mayflies as was the Station CG-1 July sample. This fact, together with similar decreases in diversity and the number of taxa occurring at both stations during this month, suggests that the Station YC-1 macroinvertebrate fauna may also have been affected by flash flooding in July. The relative abundance of Baetidae at Stations YC-1 and CG-1 may be attributed to the fact that these organisms often comprise a dominant component of the downstream invertebrate drift, which facilitates their early colonization of disturbed areas. In October, the benthic fauna at Station YC-1 showed signs of recovery from the summer impact. The number of taxa occurring increased more than fourfold, but diversity was low due to an overwhelming abundance of Simuliidae.

c. Station YC-2 - The faunal community at Station YC-2 is quite different from those at the two sites further upstream. Oligochaetes (Tubificidae) dominated the April sample, while amphipods (Talitridae) dominated both the July and October samples. In addition, members of the Odonata and Gastropoda were consistently encountered at Station YC-2. There was no appreciable seasonal change in the number of taxa occurring at this site. This suggests that a more stable flow regime exists in this part of Yellow Creek, since odonates generally have longer life cycles and there is no evidence of flash flood impacts at this site.

d. Station YC-3 - As was the case at Station YC-2, there was no summer depression in the number of taxa at Station YC-3. In addition, there was no significant change in taxonomic composition as compared with the baseline

data available for this site. The dominant major taxa for 1981 were Chironomidae in April, Diptera (primarily Simuliidae) in July, and Oligochaeta (Tubificidae) in October.

While the macroinvertebrate communities at Stations CG-1 and YC-1 seem to show the effects of flash flooding and the communities at Stations YC-2 and YC-3 do not, benthic macroinvertebrate samples from all four of these sites were similar in taxonomic compositions: they all had relatively low diversity values. This is characteristic of small, turbid streams in the semiarid West, where relatively silty substrates, fairly high total dissolved solids loads and appreciable fluctuations in flow are commonly found.

e. Stations WR-1 and WR-2 - The 1981 data obtained from the White River stations, WR-1 and WR-2, are not discernibly different from data of previous years. The taxonomic composition at the White River sites, while still characteristic of a turbid stream with a high dissolved solids content, is representative of a more stable, less stressful environment. The affected station, WR-2, also does not appear to differ from the control station, WR-1. The July 1981 samples for both sites showed an overwhelming dominance by Ephemeroptera (predominantly Tricorythidae). In April, Station WR-1 was dominated by Oligochaeta (Tubificidae) and Chironomidae were most abundant in October. In the April sample for Station WR-2, Trichoptera (Hydropsychidae) displayed a slight numerical predominance over the rest of the invertebrate community. The fall sample was also dominanted by trichopterans (Hydropsychidae and Brachycentridae). Dominant numbers of Hydropsychidae and Brachycentridae at the White River stations give a biological indication of the greater hydraulic capacity and stability of this stream. Members of these caddisfly families feed by filtering coarse, particulate material out of the water column. Simuliidae, which are abundant in Yellow Creek, are also filter feeders but they feed on much smaller particles, including colloidal-sized material. Neither Station WR-1 nor WR-2 experienced a summer decline in the number of taxa present such as occurred at Stations CG-1 and YC-1.

In summary, the six locations sampled in 1981 could be classified into three groups based upon macroinvertebrate data. The first group consists of Stations CG-1 and YC-1: unstable headwater streams with benthic fauna which appear to be affected by highly variable discharge regimes and fairly stressful water quality conditions. The second group includes the lower Yellow Creek Stations, YC-2 and YC-3: a hydraulically more stable system, but stressed primarily by naturally occurring water quality conditions. The last group consists of Stations WR-1 and WR-2 on the White River: a larger, even more stable and less stressful system with respect to both hydraulic and water quality parameters.

4.3 SUMMARY

Physical parameters examined at each of the aquatic sampling stations indicate seasonal as well as annual variability. Few trends or major changes in the physical measurements could be detected from the data. Station CG-1 experienced an increase in flow as compared with baseline conditions.

Water quality measurements made in 1981 indicated no significant changes in White River water quality upstream from its confluence with Yellow Creek, except for a possible increase in TDS at Station WR-2 in October. Examination of the 1981 data for the stations on Corral Gulch and Yellow Creek indicates a general and substantial downstream increase in dissolved solids.

Annual variations in periphyton densities occur on a seasonal basis and are directly related to such highly variable environmental parameters as current velocity, temperature, light, spring runoff, turbidity and substrate type. The 1981 density estimates at Station CG-1 were lower than the baseline values, and changes in species composition indicate a slightly higher detrital load. Changes in species dominance over time at this site could be naturally induced since such changes are not uncommon in aquatic habitats like Corral Gulch, which exhibits a high degree of variability in environmental parameters.

Station YC-3 on Yellow Creek has spring and fall periphyton communities which appear to be dominated by a group of diatoms whose relative abundance varies annually. There has been an increasing summer trend of green algal dominance at Station YC-3 during the MDP monitoring studies from 1978 through 1981.

Station WR-1 on the White River, upstream from any project influence, has shown changes in periphyton density and species diversity similar to Station WR-2, which is on the White River downstream from the confluence of Yellow Creek. Therefore, it appears that Tract C-a project activities have little or no effect on the periphyton communities of the White River.

The macroinvertebrate fauna at Station CG-1 are characteristic of the fluctuating conditions common to small streams in semiarid regions. Station CG-1 is located in an unstable area characterized by changing flow and turbidity. As might be expected under such conditions, seasonal changes in macroinvertebrate densities occurred at this station in 1981. The low densities in July are probably attributable to the flash flood which occurred just prior to sampling. There was no discharge of water from project dewatering activities during 1981, so it is likely that other seasonal changes observed at the station in 1981 were due to natural causes.

Yellow Creek is a small creek also affected by natural fluctuations in hydraulic and water quality parameters. The upper Yellow Creek station, YC-1, showed similarities to Station CG-1 in seasonal changes in macroinvertebrate densities. Stations YC-2 and YC-3 on lower Yellow Creek have similar macroinvertebrate communities characterized by organisms tolerant of unstable flow and turbidity conditions.

The White River does not appear to have been directly affected by operations on Tract C-a. The macroinvertebrate communities at Stations WR-1 and WR-2 can be described as normal for a western stream the size of the White River; however, they are substantially more diverse and stable than the communities of Corral Gulch and Yellow Creek.

LITERATURE CITED

Beck, W.M., Jr. 1977. Environmental requirements and pollution tolerance of common freshwater Chironomidae. U.S. Environmental Protection Agency. Environmental Monitoring Series EPA-600/4-77-024. 261 pp.

Cairns, J., Jr. and K.L. Dickson (eds.). 1973. Biological methods for the assessment of water quality. Am. Soc. for Testing and Materials Special Technical Publication S28:1-256.

Cholnoky, B.J. 1968. Die Okologie der Diatomeen in Binnengewassern. J. Cramer. Lehr. 699 pp.

Harris, T.L. and T.M. Lawrence. 1978. Environmental requirements and pollution tolerance of Trichoptera. U.S. Environmental Protection Agency. Environmental Monitoring Series EPA 600/4-78-063. 310 pp.

Hart, C.W., Jr. and S.L.H. Fuller (eds.). 1974. Pollution ecology of freshwater invertebrates. Academic Press, N.Y. 389 pp.

Hilsenhoff, W.L. 1977. Use of arthropods to evaluate water quality in streams. Wisc. Dept. of Nat. Res. Tech. Bull. No. 100. Madison. 15 pp.

Hubbard, M.D. and W.L. Peters. 1978. Environmental requirements and pollution tolerance of Ephemeroptera. U.S. Environmental Protection Agency. Environmental Monitoring Series EPA-600/4-78-061. 461 pp.

Hutchinson, G.E. 1975. A treatise on limnology. III. Limnological botany. John Wiley and Sons, Inc., N.Y. 660 pp.

Hynes, H.B.N. 1960. The biology of polluted waters. Liverpool Univ. Press, Liverpool. 202 pp.

_____. 1970. The ecology of running waters. Univ. of Toronto Press, Toronto. 555 pp.

Kolkowitz, R. and M. Marsson. 1909. Ecology of animal saprobia. Int. Rev. Hydrobiology and Hydrogeography. 2:126-153.

Lowe, R.L. 1974. Environmental requirements and pollution tolerance of freshwater diatoms. U.S. Environmental Protection Agency. Environmental Monitoring Series EPA-670/4-74-005. 334 pp.

Merritt, R.W. and K.W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Co. 441 pp.

Patrick, R. and C. Reimer. 1966. Diatoms of the United States. I. Monographs of the Academy of Natural Sciences of Philadelphia 13. 688 pp.

_____. 1975. Diatoms of the United States. II, Part I. Monographs of the Academy of Natural Sciences of Philadelphia 13. 213 pp.

Patrick, R. 1977. Ecology of freshwater diatoms - diatom communities. Pages 284-332. In: D. Werner (ed.). The biology of diatoms. Bot. Mono. Vol. 13. Univ. of Calif. Press, Berkeley. 498 pp.

Rio Blanco Oil Shale Company. 1978. Modular Development Phase Monitoring Report 5, December 1978 - November 1979. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____. 1980. Modular Development Phase Monitoring Report 5, December 1978 - November 1979. Gulf Oil Corp. and Standard Oil Co. (Indiana).

Round, F.E. 1973. The biology of algae. Second Edition. St. Martin's Press, England. 178 pp.

Russell, P.P. 1979. Application of laboratory-scale model streams toward assessing effluent impacts in freshwater lotic environments. Paper presented to the ASTM symposium on "The ecological assessment of effluent impacts on communities of indigenous aquatic organisms" on January 29, 1979 in Ft. Lauderdale, Florida.

Smith, G.W. 1950. The freshwater algae of the United States. McGraw-Hill Book Co., New York. 719 pp.

Surdick, R.F. and A.R. Gaufin. 1978. Environmental requirements and pollution tolerance of Plecoptera. U.S. Environmental Protection Agency. Environmental Monitoring Series EPA-600/4-78-062. 417 pp.

Tarzwell, C.M. (ed.). 1965. Biological problems in water pollution: third seminar 1962. U.S. Public Health Service. Division of Water Supply and Pollution Control. Cincinnati. 424 pp.

Ward, J.V. and R.G. Dufford. 1979. Longitudinal and seasonal distribution of macroinvertebrates and epilithic algae in a Colorado springbrook-pond system. Arch. Hydrogbiol. 86(3):284-321.

Whitton, B.A. 1970. Biology of Cladophora in freshwaters. Water Research 4:457-476.

SECTION 5
HYDROLOGY STUDIES

5.0 INTRODUCTION

During 1981, the hydrology monitoring program was modified to focus on four proposed major development activities or areas on Tract C-a (RBOSC 1981):

1. Dewatering/Reinjection/Discharge
2. MIS Modular Development Area
3. Open Pit
4. Lurgi Plant Site

The discussion of the 1981 monitoring program is divided into three sections corresponding to above-listed items 1, 2, and 4. The development of the open pit and hence the environmental monitoring of this activity has been deferred and will not be considered in this report. The Lurgi plant site construction has also been deferred, but some collection of background data was included in the 1981 monitoring effort and is considered in this report.

Data on surface water, ground water, and development activities (e.g. ponds and surface discharges) monitoring are included. The surface water monitoring program includes data from the U.S. Geological Survey (USGS) gaging stations located on or near Tract C-a and from measurements taken at the springs and seeps in the area. Ground water data have been collected from alluvial, upper aquifer, and lower aquifer monitor wells.

The development activities monitoring program includes sampling of the quantity and quality of waters associated with operations on Tract C-a. Monitoring stations include ponds, piezometers, leachate collectors, flumes, and other surface flow monitoring sites, and the various components of the dewatering/ reinjection system. These monitoring stations are in the immediate proximity of development activities.

Brief data summaries and analyses needed to support discussion of the monitoring data are presented in this section. Raw data and detailed analyses are provided in Appendix 5.

The hydrology monitoring stations have been classified as follows:

- Type I - control stations not expected to be influenced by a given set of development activities

- Type II - stations expected to detect direct, short-term impacts, should impacts result from development; such stations are located generally downgradient from development activities or operations.

- Type III - stations expected to detect indirect or long-term impacts; should impacts result from development; such stations are located downgradient from development in far-field areas.

The grouping of monitoring stations allows for spatial as well as temporal comparison of water quality and physical parameters. Thus "pre-" and "post-" development levels and the "control" vs "potentially affected" areas can be compared. The approach to designating station groups involved clustering stations initially based on knowledge of the hydrogeologic system and of potential impacts from development. These preliminary groupings are to be evaluated statistically. The results of the statistical evaluations will be employed to refine the groupings as well as to form a basis for the identification of impacts.

The hydrology monitoring program and the associated data management and data analysis activities are being upgraded at this time to enhance the utility of the data collected. Activities during the past year have included compiling and reformatting the data bases from past years and screening to identify data entry and other errors. Consistent formats for plotting and tabulating the data are being designed to provide for efficient evaluation of data as they are collected. Because these activities are in progress, the data analyses and presentations in this report constitute part of the transition to the modified hydrology monitoring program.

5.1 DEWATERING/REINJECTION/DISCHARGE PROGRAM

A. Objectives and Methods

The objectives of this program are to monitor the operation of the dewatering/reinjection system and to measure the effects on surface and ground water systems. The upper aquifer in the vicinity of the MIS area has been dewatered to allow mining and retorting operations. The existing system is designed to maintain the cone of depression; reinjecting near-mine ground water downgradient from the mine. Alternatively, the dewatering flow can be released to surface stream channels. The major potential effects of this development activity are changes in ground water levels and surface flows (during periods of surface release). In addition to water level and flow data, general water quality parameters (pH, water temperature, and specific conductance) are sampled. Sampling methods are as described in previous MDP monitoring reports.

Stations included in the dewatering/reinjection/discharge monitoring program are as follows (RBOSC 1981):

Station Class	Station and Identification	
Type I Control	Springs & Seeps	
	SPG-3	SPG-8
	SPG-4	SPG-MILL
	SPG-5	
	Deep Aquifer	
	GS-M9U	AM-3U
	GS-M10U	GS-9U
	GS-M11U	AM-2U
	GS-M12U	
	CE-708U	

Type II Near-Field	Active Dewatering Wells	
	GS-D6U	GS-D8U
	Mine Seepage	
	MISUMP (discharge to Jeffrey Pond)	
	Active Reinjection Wells	
	YCOINJ	GS-6U
	TO-2U	GS-20U
	GS-4-5U	GS-21U
	TO-3U	
	Discharge Sites/Streams	
	YFLDIS	
	Deep Aquifer	
	GS-D5U	
	GS-D1U	
	GS-D4U	
	GS-MDP2CU	CE-702U
Type III Far-Field	Streams	
	E-USGS	
	YLDGEDGE	
	Deep Aquifer	
	GS-M2U	GS-M5U
	GS-M3U	GS-11U
	GS-10U	GS-13U
	GS-12U	
	GS-19L	CE-702L
	GS-M4L	GS-17L

B. Results and Discussion

The monitoring data have been examined for temporal and spatial variations. Temporal changes were examined by comparing 1981 univariate statistics (e.g., mean and maximum values) for the above-listed monitoring station groups with similar statistics for previous years. Where possible, comparisons were made between 1981 and 1980 (the previous monitoring year) and 1976 (the last year of the baseline monitoring period). Spatial changes are examined by comparison of univariate statistics for upper aquifer wells divided into control, near-

field, and far-field station groups. In addition, a multivariate analysis of variance (MANOVA) procedure was used to test the significance of temporal and spatial variability and space-time interactions.

1. Dewatering/Reinjection System

The cone of depression resulting from operation of the dewatering/reinjection system was relatively stable throughout 1981. Comparison of the cone of depression observed in October 1980 (Figure 5-1) with October 1981 (Figure 5-2) indicates some elongation of the 200-foot contour in the northwest-southeast direction and some lessening of the 100-foot and 20-foot contours in this same dimension. The total area affected by the operation during 1981 was not substantially different from that of 1980.

During 1981, the dewatering operation included the use of dewatering wells (GS-D6U and GS-D8U) and the mine sumps. The stability of the operation noted above is further shown in the 1981 plots of flow and water level for GS-D6U (Figure 5-3). Use of dewatering wells was terminated in late November 1981. Since then, dewatering has been accomplished thru mine-sump discharges. Dewatering flows were all reinjected or consumed during 1981; no water was discharged to the surface from this operation.

Six wells were used for reinjection during 1981. The general pattern of reinjection flow is summarized as follows (Appendix 5-1.1):

- GS-20U
  - over 700 gpm January-May
  - approximately 275 gpm June-November
  - increasing to about 600 gpm by end of year
- GS-21U
  - approximately 100 gpm January-May
  - zero thereafter
- GS-4-5U
  - 200-250 gpm January-November
  - 100 gpm in December

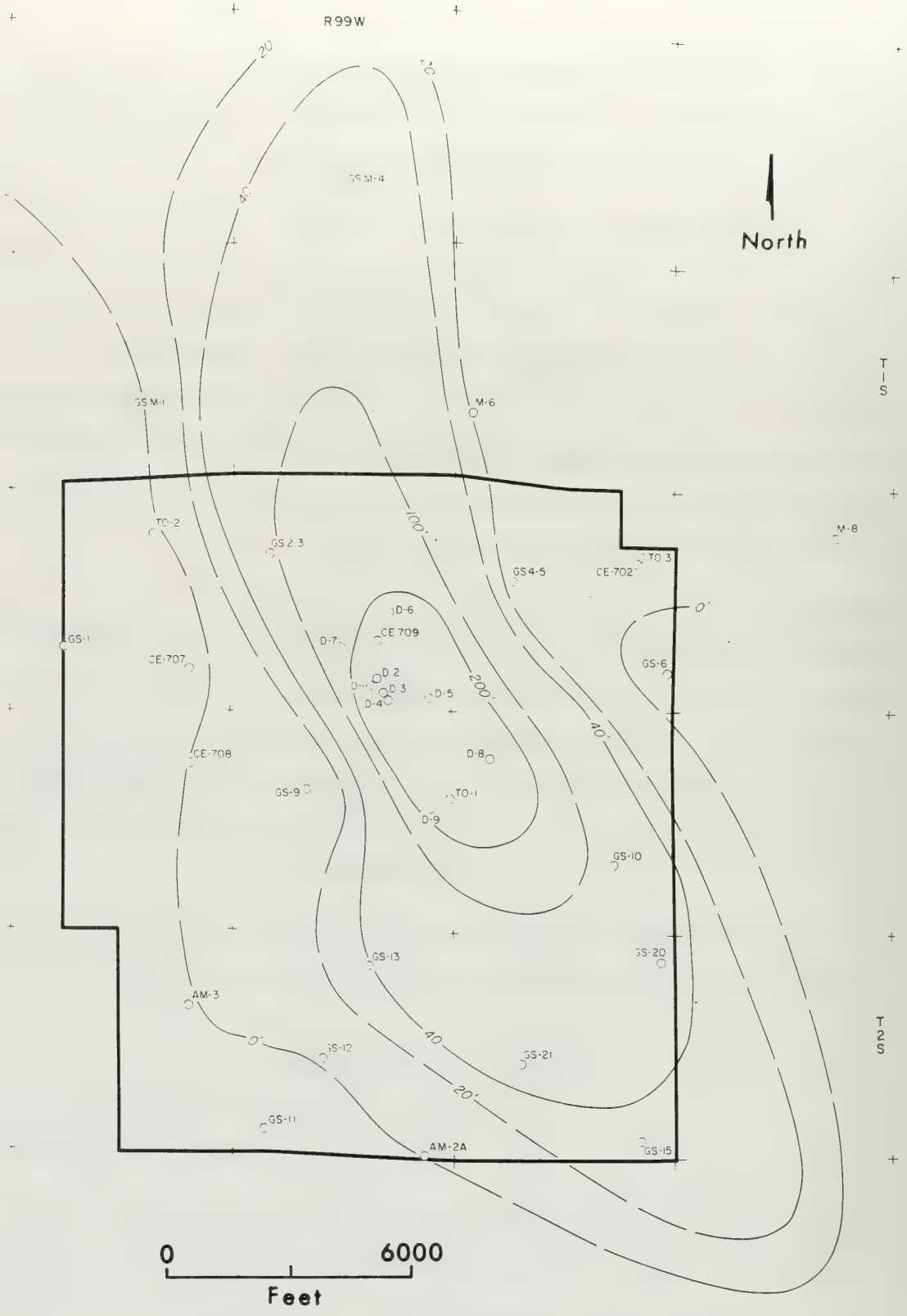


Figure 5-1. Upper Aquifer Cone of Depression October 15, 1980

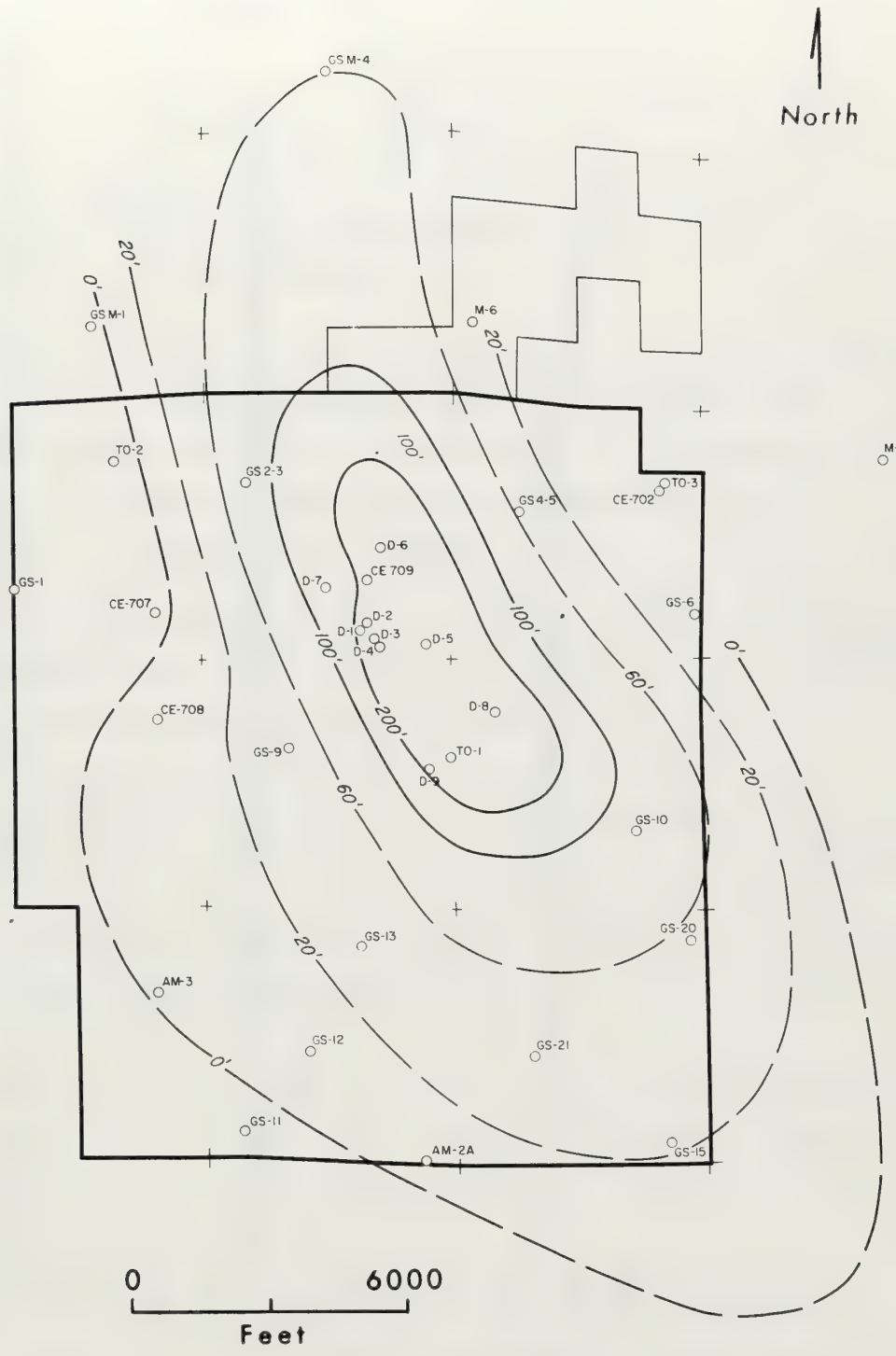


Figure 5-2. Upper Aquifer Cone of Depression October, 1981

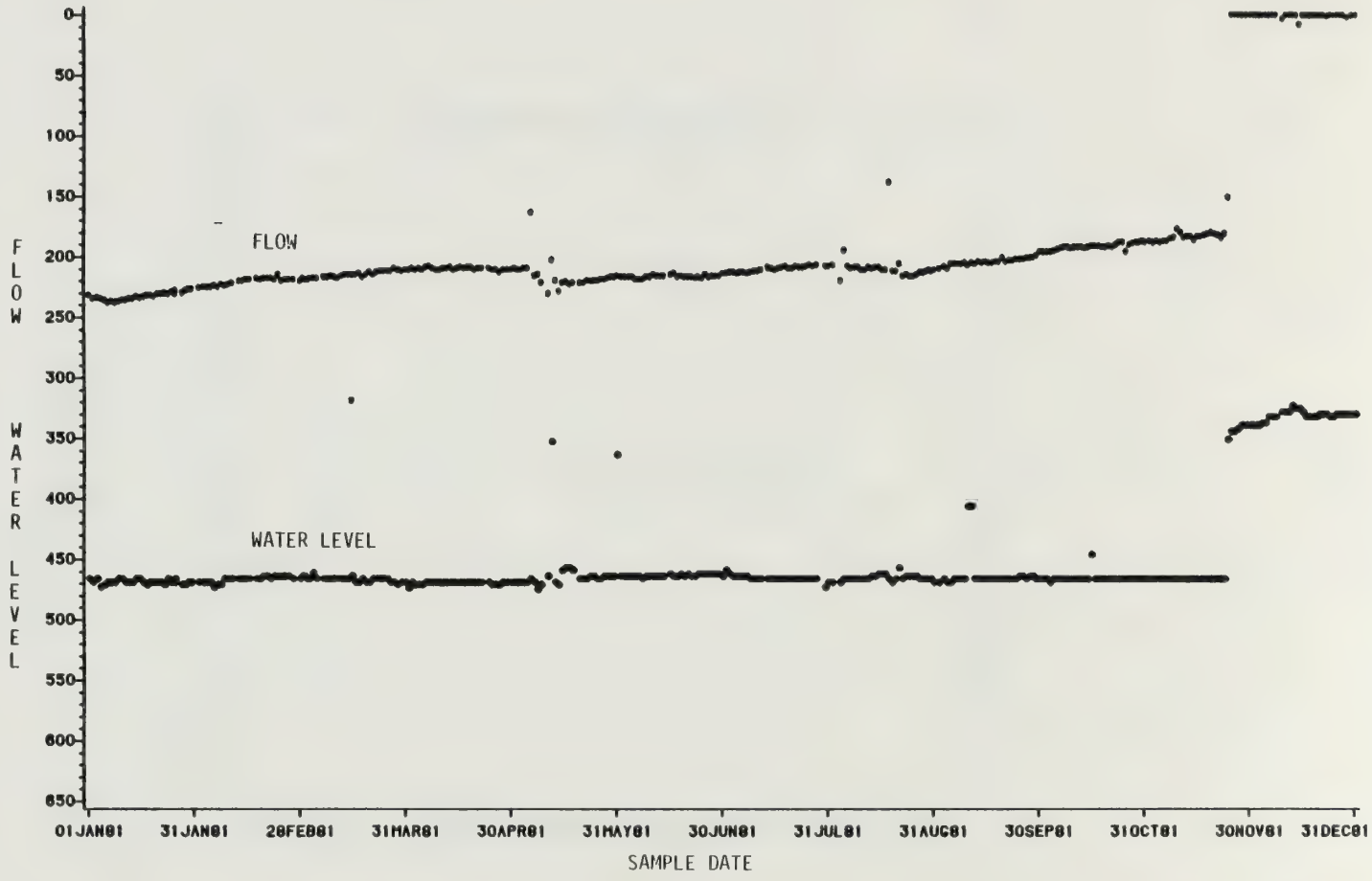


Figure 5-3. Water Level (Depth to Water, Feet) and Flow (gpm) Measurements at Station GS-D6U During 1981

- GS-6U - 200-400 gpm January-May
  - up to 700 gpm in June, decreasing to 100 gpm in December

- TO-2U - steady decline from 250 gpm in January to about 175 gpm in December

- TO-3U - 150-200 gpm January-November
  - 50 gpm in December

The water quality of the dewatering/reinjection/discharge system was monitored by sampling the composite reinjection water (YCOINJ); the Jeffrey Pond (YJEFFPOND), which receives water from the mine sumps; and dewatering wells GS-D6U and GS-D8U. Water quality data from these stations is shown in Tables 5-1, 5-2, and 5-3, respectively (Appendix 5-1.2).

The water quality of the Jeffrey Pond was very similar to that of the composite reinjection water except that the pH in the pond (maximum of 8.4) was higher than that of the composite reinjection water (maximum of 7.7).

Wells GS-D6U and GS-D8U were active dewatering wells during most of 1981. In 1981, the mean concentrations of most constituents were very similar to means of the composite reinjection water. The bicarbonate alkalinity levels in GS-D8U tended to be greater by 100-150 mg/l than at GS-D6U, in the composite reinjection water, or in the Jeffrey Pond.

The conductivity and pH of reinjection flows were fairly constant throughout 1981 (Figures 5-4 and 5-5). Similar values of pH and conductivity were observed in the Jeffrey and West Retention Ponds, both of which receive water from the mine-sump system.

Mean concentrations of dissolved constituents in the composite reinjection water during 1981 (Table 5-1) were generally comparable to those of 1979 and 1980. Maximum concentrations were also comparable, although several decreased between 1980 and 1981:

Table 5-1. Summary of Water Quality Data for Composite Reinjection Water (YCOINJ), 1981

TYPE=DEVELOPMENT ACTIVITIES MONITORING SYSTEM STATION = YCOINJ REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	3	7.70	0.00	7.70	7.70	7.70	7.70
CONDUCTIVITY	3	1416.67	72.17	1500.00	1375.00	1375.00	1500.00
TOT DIS SOLIDS	3	1046.67	12.86	1056.00	1032.00	1032.00	1056.00
ALKALINITY	3	489.33	9.61	498.00	479.00	479.00	498.00
CALCIUM	3	41.33	2.52	44.00	39.00	39.00	44.00
MAGNESIUM	3	77.00	1.00	78.00	76.00	76.00	78.00
POTASSIUM	3	0.42	0.03	0.44	0.39	0.39	0.44
SODIUM	3	196.67	11.55	210.00	190.00	190.00	210.00
BICARBONATE	3	567.33	9.29	578.00	561.00	561.00	578.00
CARBONATE	1	1.00	.	1.00	1.00	1.00	1.00
CHLORIDE	3	7.22	1.76	8.29	5.19	5.19	8.29
NITRATE	3	0.37	0.12	0.50	0.30	0.30	0.50
SULFATE	3	377.00	18.19	388.00	356.00	356.00	388.00
FLUORIDE	3	0.48	0.17	0.62	0.29	0.29	0.62
AMMONIA	3	0.51	0.36	0.80	0.10	0.10	0.80
PHOSPHATE	2	0.13	0.04	0.16	0.10	0.10	0.16
BORON	2	0.25	0.02	0.27	0.24	0.24	0.27
SILICA	3	29.00	1.00	30.00	28.00	28.00	30.00
IRON	2	0.06	0.01	0.07	0.06	0.06	0.07
DIS ORG CARBON	3	5.67	3.21	8.00	2.00	2.00	8.00
ARSENIC	1	0.01	.	0.01	0.01	0.01	0.01
SELENIUM	1	0.01	.	0.01	0.01	0.01	0.01
VANADIUM	1	0.50	.	0.50	0.50	0.50	0.50
MOLYBDENUM	1	0.10	.	0.10	0.10	0.10	0.10
MERCURY	1	0.30	.	0.30	0.30	0.30	0.30
ALUMINUM	1	0.10	.	0.10	0.10	0.10	0.10
BARIUM	1	0.10	.	0.10	0.10	0.10	0.10
BERYLLIUM	1	0.01	.	0.01	0.01	0.01	0.01
BISMUTH	1	0.01	.	0.01	0.01	0.01	0.01
BROMIDE	1	0.20	.	0.20	0.20	0.20	0.20
CADMIUM	1	0.01	.	0.01	0.01	0.01	0.01
CHROMIUM	1	0.01	.	0.01	0.01	0.01	0.01
COPPER	1	0.01	.	0.01	0.01	0.01	0.01
GALLIUM	1	0.50	.	0.50	0.50	0.50	0.50
GERMANIUM	1	0.10	.	0.10	0.10	0.10	0.10
LEAD	1	0.10	.	0.10	0.10	0.10	0.10
LITHIUM	1	0.12	.	0.12	0.12	0.12	0.12
MANGANESE	1	0.01	.	0.01	0.01	0.01	0.01
NICKEL	1	0.05	.	0.05	0.05	0.05	0.05
STRONTIUM	1	5.20	.	5.20	5.20	5.20	5.20
TITANIUM	1	0.50	.	0.50	0.50	0.50	0.50
ZINC	1	0.01	.	0.01	0.01	0.01	0.01
ZIRCONIUM	1	10.00	.	10.00	10.00	10.00	10.00

Table 5-2. Summary of Water Quality Data for Jeffery Pond (YJEFFPOND), 1981

TYPE=DEVELOPMENT ACTIVITIES MONITORING SYSTEM STATION = YJEFFPOND REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	3	8.20	0.26	8.40	7.90	7.90	8.40
CONDUCTIVITY	3	1416.67	38.19	1450.00	1375.00	1375.00	1450.00
TOT DIS SOLIDS	2	1034.50	34.65	1059.00	1010.00	1010.00	1059.00
ALKALINITY	2	487.50	2.12	489.00	486.00	486.00	489.00
CALCIUM	2	35.50	0.71	36.00	35.00	35.00	36.00
MAGNESIUM	2	80.00	0.00	80.00	80.00	80.00	80.00
POTASSIUM	2	0.40	0.11	0.48	0.32	0.32	0.48
SODIUM	2	197.00	4.24	200.00	194.00	194.00	200.00
BICARBONATE	2	565.50	6.36	570.00	561.00	561.00	570.00
CARBONATE	0	.	.	.	.	.	.
CHLORIDE	2	10.66	2.18	12.20	9.12	9.12	12.20
NITRATE	2	0.10	0.00	0.10	0.10	0.10	0.10
SULFATE	2	380.00	4.24	383.00	377.00	377.00	383.00
FLUORIDE	2	0.84	0.79	1.40	0.28	0.28	1.40
AMMONIA	0	.	.	.	.	.	.
PHOSPHATE	1	0.07	.	0.07	0.07	0.07	0.07
BORON	2	0.18	0.11	0.26	0.10	0.10	0.26
SILICA	2	22.50	2.12	24.00	21.00	21.00	24.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	2	3.00	0.00	3.00	3.00	3.00	3.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	2	1.75	2.05	3.20	0.30	0.30	3.20
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	0	.	.	.	.	.	.
MANGANESE	0	.	.	.	.	.	.
NICKEL	0	.	.	.	.	.	.
STRONTIUM	0	.	.	.	.	.	.
TITANIUM	0	.	.	.	.	.	.
ZINC	0	.	.	.	.	.	.
ZIRCONIUM	0	.	.	.	.	.	.

Table 5-3. Summary of Water Quality Data for Dewatering Wells GS-D6U and GS-D8U, 1981

AREA=NEAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	9	7.64	0.24	8.10	7.30	7.30	8.10
CONDUCTIVITY	9	1407.78	72.55	1550.00	1320.00	1320.00	1550.00
TOT DIS SOLIDS	7	1032.14	67.88	1120.00	940.00	940.00	1120.00
ALKALINITY	9	496.00	61.70	572.00	434.00	434.00	572.00
CALCIUM	7	50.29	6.10	57.00	44.00	44.00	57.00
MAGNESIUM	7	74.29	16.36	90.00	56.00	56.00	90.00
POTASSIUM	7	0.31	0.08	0.49	0.25	0.25	0.49
SODIUM	7	198.86	12.94	217.00	180.00	180.00	217.00
BICARBONATE	9	578.78	75.87	674.00	508.00	508.00	674.00
CARBONATE	2	1.00	0.00	1.00	1.00	1.00	1.00
CHLORIDE	7	10.54	5.65	22.90	5.97	5.97	22.90
NITRATE	6	0.15	0.08	0.20	0.00	0.00	0.20
SULFATE	7	355.86	56.49	443.00	263.00	263.00	443.00
FLUORIDE	7	0.47	0.36	0.94	0.11	0.11	0.94
AMMONIA	7	0.79	0.90	2.29	0.07	0.07	2.29
PHOSPHATE	5	0.05	0.04	0.11	0.01	0.01	0.11
BORON	7	0.27	0.08	0.38	0.17	0.17	0.38
SILICA	7	32.71	3.04	36.00	27.00	27.00	36.00
IRON	3	0.16	0.03	0.20	0.14	0.14	0.20
DIS ORG CARBON	6	5.83	5.27	16.00	1.00	1.00	16.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	1	7.90	.	7.90	7.90	7.90	7.90
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	2	0.85	0.07	0.90	0.80	0.80	0.90
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	4	0.10	0.01	0.12	0.09	0.09	0.12
MANGANESE	2	0.03	0.01	0.04	0.02	0.02	0.04
NICKEL	0	.	.	.	.	.	.
STRONTIUM	4	5.06	0.42	5.50	4.51	4.51	5.50
TITANIUM	0	.	.	.	.	.	.
ZINC	2	0.03	0.03	0.05	0.01	0.01	0.05
ZIRCONIUM	0	.	.	.	.	.	.

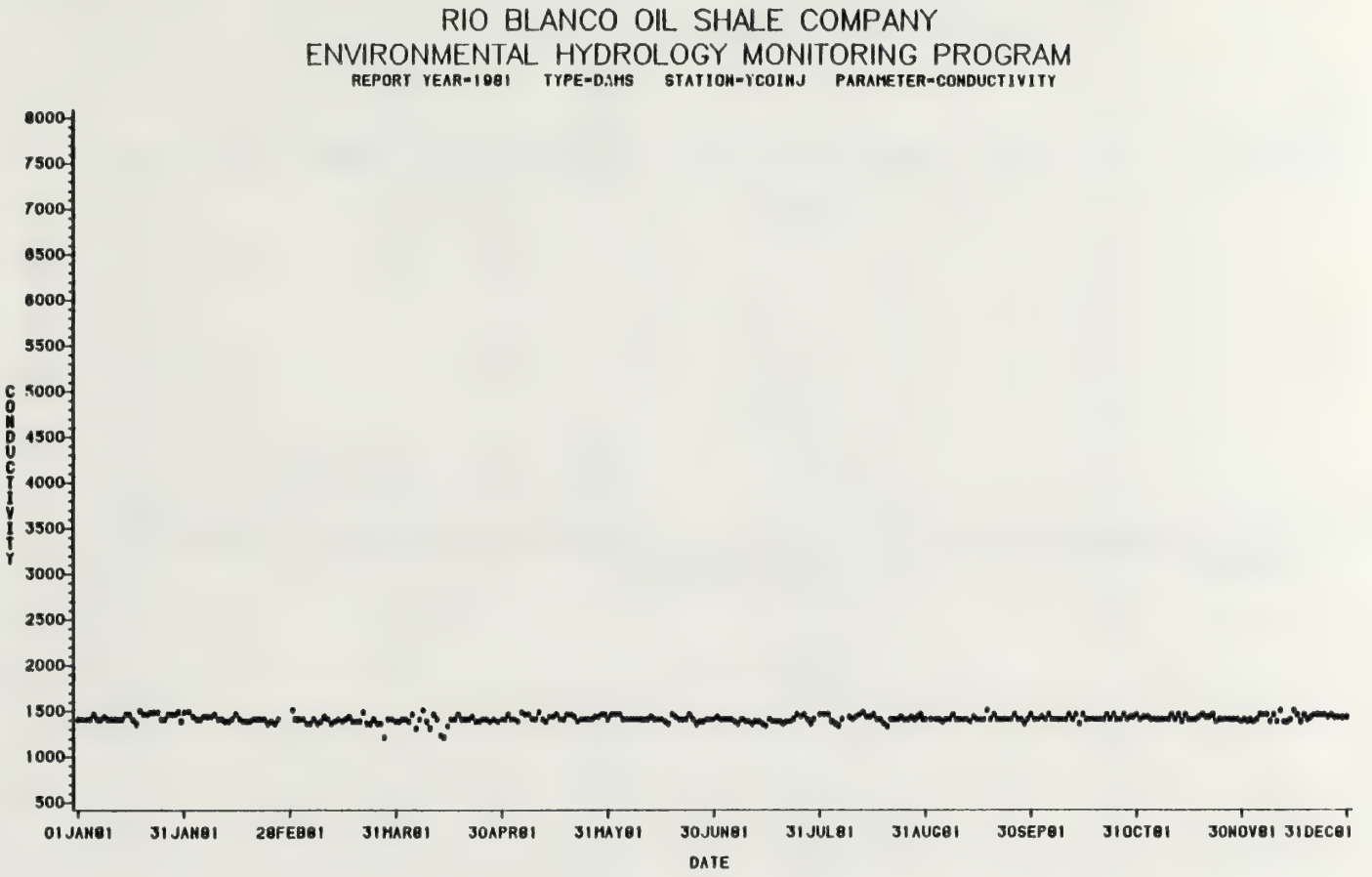


Figure 5-4. Conductivity (micromhos per cm) of Composite Reinjection Water (YCOINJ) During 1981

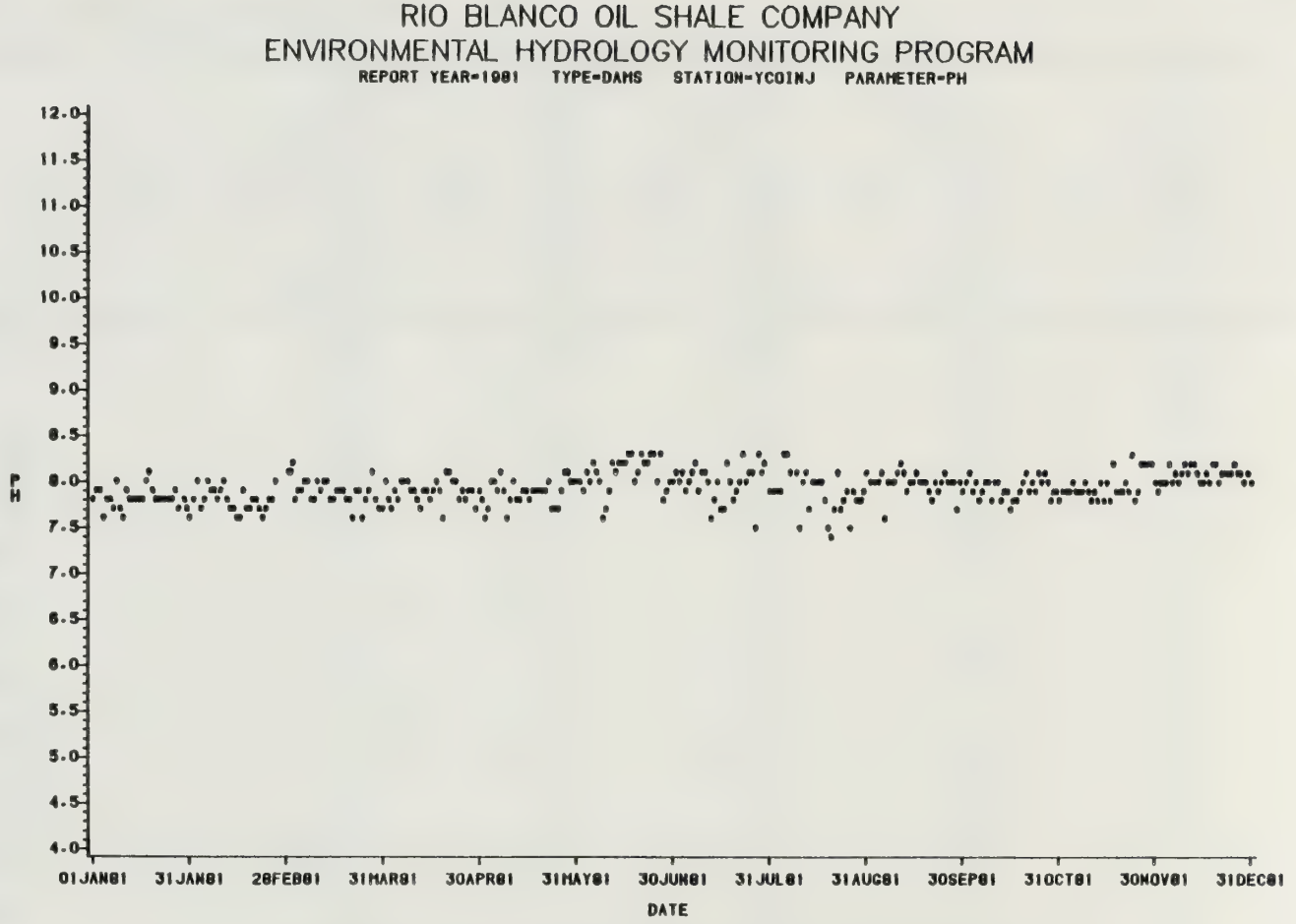


Figure 5-5. Composite Reinjection Water (YCOINJ) pH During 1981

Parameter	1981 Maximum	1980 Maximum
Calcium	44	80
Magnesium	78	97
Chloride	8.3	13.6
Sulfate	388	494

In addition, the variability (standard deviation) of many dissolved constituents data decreased in 1981 relative to 1980.

2. Springs and Seeps

The 1981 water quality data collected at control spring stations are summarized in Table 5-4. Springs and seeps data are presented in Appendix 5-1.3. Although means for most constituents were not greatly different from 1980 means, several increases were noted:

Parameter	1981 Mean	1980 Mean
TDS (Total Dissolved Solids)	932	833
Sodium	118	96
Bicarbonate	521	506
Chloride	18	11
Sulfate	345	307

These increases are largely due to the addition of SPG-MILL (Miller's Spring) to the 1981 monitoring program. With the exception of calcium and chloride, all of the maximum levels for the 1981 data set are SPG-MILL observations. For this reason, 1981 maximum concentrations of many constituents were greater than 1980 maxima (Miller's spring was not sampled in 1980):

Table 5-4. Summary of Water Quality Data for Springs and Seeps, Dewatering/Reinjection/Discharge Program, 1981

TYPE=SEEP AREA=CONTROL REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	17	7.91	0.39	8.90	7.20	7.20	8.90
CONDUCTIVITY	17	1152.35	260.47	1775.00	900.00	900.00	1775.00
TOT DIS SOLIDS	6	931.50	195.46	1305.00	754.00	754.00	1305.00
ALKALINITY	9	448.44	137.32	694.00	342.00	342.00	694.00
CALCIUM	6	110.00	18.71	140.00	85.00	85.00	140.00
MAGNESIUM	6	67.17	11.86	88.00	56.00	56.00	88.00
POTASSIUM	6	1.61	0.45	2.20	0.88	0.88	2.20
SODIUM	6	118.00	57.95	230.00	77.00	77.00	230.00
BICARBONATE	9	521.44	168.95	821.00	379.00	379.00	821.00
CARBONATE	1	1.21	.	1.21	1.21	1.21	1.21
CHLORIDE	6	17.98	13.41	43.60	7.95	7.95	43.60
NITRATE	5	0.70	0.45	1.20	0.20	0.20	1.20
SULFATE	6	344.67	69.84	420.00	253.00	253.00	420.00
FLUORIDE	6	0.30	0.08	0.37	0.17	0.17	0.37
AMMONIA	3	0.84	0.55	1.40	0.31	0.31	1.40
PHOSPHATE	4	0.08	0.02	0.10	0.07	0.07	0.10
BORON	6	0.29	0.15	0.45	0.13	0.13	0.45
SILICA	6	19.83	4.26	26.00	15.00	15.00	26.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	13	7.23	4.17	16.00	3.00	3.00	16.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	0	.	.	.	.	.	.
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	4	0.03	0.02	0.06	0.01	0.01	0.06
MANGANESE	3	0.08	0.08	0.17	0.03	0.03	0.17
NICKEL	0	.	.	.	.	.	.
STRONTIUM	4	1.50	0.37	1.87	1.13	1.13	1.87
TITANIUM	0	.	.	.	.	.	.
ZINC	1	0.03	.	0.03	0.03	0.03	0.03
ZIRCONIUM	0	.	.	.	.	.	.

Parameter	1981 Maximum	1980 Maximum
TDS	1305	956
Alkalinity	694	497
Calcium	140	129
Magnesium	88	78
Sodium	230	147
Bicarbonate	821	582
Chloride	44	16
Sulfate	420	398

In contrast to the increases in inorganic constituents, the mean dissolved organic carbon (DOC) concentration for this set of monitoring stations was greatly decreased in 1981 (7.2 mg/l) relative to 1980 (42 mg/l).

3. Upper Aquifer

a. Field Data - Summaries of upper aquifer 1981 field summaries for control, near-field and far-field station groups are presented in Table 5-5. Data are presented in Appendix 5-1.4. Control station water levels (mean 177.3 feet, maximum 439.0 feet, and minimum 23.3 feet) are comparable to those of 1980. Similarly, 1981 water temperature and pH levels are comparable to 1980 data. Baseline water levels at these control stations were somewhat shallower with a 1975 mean water level (depth to water) of 134.3 feet and 1976 mean of 132.9 feet. This comparison shows a moderate effect of dewatering on these wells.

The 1981 mean specific conductance (1579 micromhos/cm) at upper aquifer control wells was greater than the means for either 1979 or 1980 (1170 and 1132 micromhos/cm, respectively). This increase is due largely to a single observation of 3000 micromhos/cm at GS-M9U during 1980.

Comparisons of field data for 1981 with data from previous years could not be made for near-field upper aquifer stations since only water levels were observed prior to 1981. Water levels in the near-field have declined up to

Table 5-5. Summary of Field Data from Upper Aquifer Wells, Dewatering/Reinjection/Discharge Program, 1981

TYPE=UPPA AREA=CONTROL REPORT YEAR=1981

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
WATER LEVEL	189	177.28	162.13	439.00	23.30	23.65	437.70
TEMPERATURE	6	11.03	1.83	13.10	8.40	8.40	13.10
CONDUCTIVITY	6	1579.17	705.06	3000.00	1100.00	1100.00	3000.00
PH	6	7.60	0.46	8.30	7.00	7.00	8.30

TYPE=UPPA AREA=NEAR FIELD REPORT YEAR=1981

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
WATER LEVEL	533	469.40	117.14	599.30	83.00	231.10	597.90
TEMPERATURE	173	16.28	1.17	18.50	13.60	14.50	17.86
CONDUCTIVITY	173	1390.46	75.44	1625.00	1200.00	1275.00	1500.00
PH	173	7.73	0.20	8.50	7.30	7.40	8.10

TYPE=UPPA AREA=FAR FIELD REPORT YEAR=1981

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
WATER LEVEL	423	237.83	188.51	556.30	10.90	11.36	550.80
TEMPERATURE	12	12.64	2.21	15.60	8.80	8.80	15.60
CONDUCTIVITY	12	1656.25	251.84	2050.00	1300.00	1300.00	2050.00
PH	12	7.81	0.87	9.70	6.90	6.90	9.70

100-200 feet due to mine dewatering. Mean far-field water levels for 1981 (237.8 feet) were comparable to 1980 levels (mean 235.0 feet) and somewhat shallower than the 1976 mean (261.9 feet). The 1981 water temperature and pH observations were generally comparable to 1980 and 1979 data. Specific conductance in far-field wells was comparable to earlier observations. Maximum far-field conductivity has consistently been measured at GS-M5U.

Spatial gradients in field data were observed during 1981 (Table 5-5). As a consequence of dewatering, water levels are lowest at near-field stations. Water temperatures are generally comparable but somewhat higher at near-field stations than at control and far-field stations. Water pH generally increased from control to near-field to far-field upper aquifer wells which may reflect the changes in geochemical equilibrium resulting from the dewatering/reinjection activities. Observed specific conductance was generally lower in the near-field wells relative to the control or far-field upper aquifer wells. This may be due to possible bias in the station grouping which includes wells GS-M5U in the far-field and GS-M9U (which exhibit relatively high conductivity) in the control station groupings.

b. Water Quality Data - Results of water quality analyses of samples collected as part of the 1981 dewatering/reinjection/discharge monitoring program are summarized in Tables 5-6, 5-7, and 5-8. Data listings are presented in Appendix 5-1.5. Mean concentrations in upper aquifer control wells during 1981 were generally similar to 1980 values; however, several major ions showed decreases in 1981:

Parameter	1981 Mean	1980 Mean	1976 Mean
TDS	1064	1226	921
Calcium	85	118	64
Magnesium	77	88	55
Bicarbonate	523	552	521
Sulfate	433	492	316

Table 5-6. Summary of Water Quality Data for Upper Aquifer Control Wells, Dewatering/Reinjection/ Discharge Program, 1981

TYPE=UPPA AREA=CONTROL REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	18	7.59	0.47	8.30	6.70	6.70	8.30
CONDUCTIVITY	19	1343.68	674.96	3000.00	-200.00	-200.00	3000.00
TOT DIS SOLIDS	19	1064.47	552.70	2644.00	706.00	706.00	2644.00
ALKALINITY	19	450.74	115.18	771.00	374.00	374.00	771.00
CALCIUM	19	85.27	62.92	266.00	33.00	33.00	266.00
MAGNESIUM	19	77.26	45.46	203.00	44.00	44.00	203.00
POTASSIUM	19	0.73	0.45	1.86	0.34	0.34	1.86
SODIUM	19	153.05	43.99	260.00	101.00	101.00	260.00
BICARBONATE	19	523.21	140.41	910.00	425.00	425.00	910.00
CARBONATE	7	1.06	0.16	1.42	1.00	1.00	1.42
CHLORIDE	19	9.11	1.59	11.30	4.85	4.85	11.30
NITRATE	10	0.49	0.82	2.40	0.10	0.10	2.40
SULFATE	19	432.58	308.22	1364.00	244.00	244.00	1364.00
FLUORIDE	19	0.31	0.25	0.94	0.09	0.09	0.94
AMMONIA	17	0.62	0.47	1.80	0.10	0.10	1.80
PHOSPHATE	17	0.11	0.11	0.39	0.01	0.01	0.39
BORON	15	0.29	0.26	1.17	0.03	0.03	1.17
SILICA	19	27.95	13.15	56.00	14.00	14.00	56.00
IRON	9	1.07	1.22	3.09	0.05	0.05	3.09
DIS ORG CARBON	16	5.75	2.35	10.00	3.00	3.00	10.00
ARSENIC	5	0.01	0.00	0.01	0.01	0.01	0.01
SELENIUM	5	0.01	0.00	0.01	0.01	0.01	0.01
VANADIUM	5	0.50	0.00	0.50	0.50	0.50	0.50
MOLYBDENUM	5	0.10	0.00	0.10	0.10	0.10	0.10
MERCURY	6	0.33	0.08	0.50	0.30	0.30	0.50
ALUMINUM	5	0.12	0.04	0.20	0.10	0.10	0.20
BARIUM	5	0.10	0.00	0.10	0.10	0.10	0.10
BERYLLIUM	5	0.01	0.00	0.01	0.01	0.01	0.01
BISMUTH	5	0.01	0.00	0.01	0.01	0.01	0.01
BROMIDE	5	0.20	0.00	0.20	0.20	0.20	0.20
CADMIUM	5	0.01	0.00	0.01	0.01	0.01	0.01
CHROMIUM	5	0.01	0.00	0.01	0.01	0.01	0.01
COPPER	5	0.01	0.00	0.01	0.01	0.01	0.01
GALLIUM	5	0.50	0.00	0.50	0.50	0.50	0.50
GERMANIUM	5	0.10	0.00	0.10	0.10	0.10	0.10
LEAD	5	0.10	0.00	0.10	0.10	0.10	0.10
LITHIUM	12	0.09	0.04	0.15	0.05	0.05	0.15
MANGANESE	11	0.08	0.10	0.37	0.02	0.02	0.37
NICKEL	5	0.05	0.00	0.05	0.05	0.05	0.05
STRONTIUM	12	2.22	0.99	3.41	0.45	0.45	3.41
TITANIUM	5	0.50	0.00	0.50	0.50	0.50	0.50
ZINC	12	0.03	0.03	0.08	0.01	0.01	0.08
ZIRCONIUM	5	10.00	0.00	10.00	10.00	10.00	10.00

Table 5-7. Summary of Water Quality Data for Upper Aquifer Near-Field Wells, Dewatering/Reinjection/ Discharge Program, 1981

TYPE=UPPA AREA=NEAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	2	8.50	0.28	8.70	8.30	8.30	8.70
CONDUCTIVITY	2	1450.00	212.13	1600.00	1300.00	1300.00	1600.00
TOT DIS SOLIDS	2	1127.50	242.54	1299.00	956.00	956.00	1299.00
ALKALINITY	2	412.00	18.38	425.00	399.00	399.00	425.00
CALCIUM	2	51.00	22.63	67.00	35.00	35.00	67.00
MAGNESIUM	2	91.00	7.07	96.00	86.00	86.00	96.00
POTASSIUM	2	0.34	0.11	0.42	0.27	0.27	0.42
SODIUM	2	170.00	28.28	190.00	150.00	150.00	190.00
BICARBONATE	2	485.00	21.21	500.00	470.00	470.00	500.00
CARBONATE	0	.	.	.	.	.	.
CHLORIDE	2	9.01	0.80	9.58	8.45	8.45	9.58
NITRATE	1	0.80	.	0.80	0.80	0.80	0.80
SULFATE	2	455.00	147.08	559.00	351.00	351.00	559.00
FLUORIDE	2	1.77	1.00	2.48	1.06	1.06	2.48
AMMONIA	0	.	.	.	.	.	.
PHOSPHATE	2	0.04	0.01	0.05	0.03	0.03	0.05
BORON	2	0.29	0.03	0.31	0.27	0.27	0.31
SILICA	2	26.50	2.12	28.00	25.00	25.00	28.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	2	9.50	0.71	10.00	9.00	9.00	10.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	0	.	.	.	.	.	.
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	2	0.16	0.06	0.20	0.12	0.12	0.20
MANGANESE	2	0.01	0.00	0.01	0.01	0.01	0.01
NICKEL	0	.	.	.	.	.	.
STRONTIUM	2	3.39	0.54	3.78	3.01	3.01	3.78
TITANIUM	0	.	.	.	.	.	.
ZINC	2	0.02	0.00	0.02	0.02	0.02	0.02
ZIRCONIUM	0	.	.	.	.	.	.

Table 5-8. Summary of Water Quality Data for Upper Aquifer Far-Field Wells, Dewatering/Reinjection/ Discharge Program, 1981

TYPE=UPPA AREA=FAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	31	8.28	1.03	9.80	7.00	7.00	9.74
CONDUCTIVITY	31	1556.13	259.70	2100.00	1200.00	1245.00	2070.00
TOT DIS SOLIDS	32	1208.19	266.36	1788.00	780.00	847.60	1733.40
ALKALINITY	32	527.53	75.09	679.00	424.00	430.50	667.95
CALCIUM	32	60.38	52.04	140.00	3.70	3.80	134.15
MAGNESIUM	32	86.97	23.63	120.00	48.00	49.30	120.00
POTASSIUM	32	1.47	1.56	6.80	0.05	0.23	5.76
SODIUM	32	219.84	39.69	270.00	140.00	140.00	270.00
BICARBONATE	32	525.00	161.34	775.00	254.00	257.25	771.10
CARBONATE	19	8.10	6.53	17.40	1.00	1.00	17.40
CHLORIDE	32	12.49	4.35	25.20	7.10	7.10	22.27
NITRATE	14	0.09	0.04	0.10	0.00	0.00	0.10
SULFATE	32	518.59	132.49	841.00	312.00	320.45	781.85
FLUORIDE	32	0.34	0.40	1.66	0.03	0.04	1.59
AMMONIA	26	0.69	0.72	2.78	0.09	0.09	2.54
PHOSPHATE	24	0.08	0.08	0.34	0.01	0.01	0.33
BORON	26	0.27	0.31	1.61	0.01	0.01	1.28
SILICA	29	23.28	16.94	48.00	0.50	0.50	48.00
IRON	14	2.39	3.50	11.10	0.05	0.05	11.10
DIS ORG CARBON	31	8.00	7.06	37.00	1.00	1.00	29.20
ARSENIC	3	0.01	0.00	0.01	0.01	0.01	0.01
SELENIUM	3	0.01	0.00	0.01	0.01	0.01	0.01
VANADIUM	3	0.50	0.00	0.50	0.50	0.50	0.50
MOLYBDENUM	3	0.10	0.00	0.10	0.10	0.10	0.10
MERCURY	3	0.30	0.00	0.30	0.30	0.30	0.30
ALUMINUM	3	0.10	0.00	0.10	0.10	0.10	0.10
BARIUM	3	0.10	0.00	0.10	0.10	0.10	0.10
BERYLLIUM	3	0.01	0.00	0.01	0.01	0.01	0.01
BISMUTH	3	0.01	0.00	0.01	0.01	0.01	0.01
BROMIDE	4	0.57	0.68	1.60	0.20	0.20	1.60
CADMIUM	4	0.01	0.00	0.01	0.01	0.01	0.01
CHROMIUM	3	0.01	0.00	0.01	0.01	0.01	0.01
COPPER	3	0.01	0.00	0.01	0.01	0.01	0.01
GALLIUM	3	0.50	0.00	0.50	0.50	0.50	0.50
GERMANIUM	3	0.10	0.00	0.10	0.10	0.10	0.10
LEAD	3	0.10	0.00	0.10	0.10	0.10	0.10
LITHIUM	10	0.13	0.04	0.20	0.08	0.08	0.20
MANGANESE	9	0.09	0.07	0.20	0.01	0.01	0.20
NICKEL	4	0.05	0.00	0.05	0.05	0.05	0.05
STRONTIUM	10	2.88	1.59	5.40	0.07	0.07	5.40
TITANIUM	3	0.50	0.00	0.50	0.50	0.50	0.50
ZINC	7	0.05	0.05	0.15	0.01	0.01	0.15
ZIRCONIUM	3	10.00	0.00	10.00	10.00	10.00	10.00

For these constituents, the 1981 means were closer to baseline (1976) means than to 1980 means. The same is apparent in yearly maximum observed concentrations at the upper aquifer control stations.

Mean concentrations observed at upper aquifer near-field wells in 1981 were commonly higher than 1980 and baseline (1976) levels:

Parameter	1981 Mean	1980 Mean	1976 Mean
TDS	1127	906	750
Calcium	51	37	32
Magnesium	91	63	41
Sulfate	455	276	245
DOC	9.5	25	11
Alkalinity	412	474	385

The mean DOC and alkalinity concentrations were lower in 1981 than in 1980 but comparable to 1976 means. These general trends were also noted in yearly maximum concentrations at near-field wells:

Parameter	1981 Maximum	1980 Maximum	1976 Maximum
TDS	1299	1016	1060
Calcium	67	64	80
Magnesium	96	74	67
Sulfate	559	353	350
DOC	10	84	18
Alkalinity	425	584	550

Mean concentrations of most major ions at far-field upper aquifer wells in 1981 were comparable or slightly lower relative to the means for 1981. This trend was also seen in yearly maximum concentrations at far-field wells:

Parameter	1981 Maximum	1980 Maximum	1976 Maximum
TDS	1788	1732	2520
Alkalinity	679	939	2390
Magnesium	120	172	170
Sodium	270	326	1160
Bicarbonate	775	868	2600
Chloride	25	48	69
Sulfate	841	770	840
DOC	37	77	18

Comparison of 1981 water quality data means for control, near-field and far-field upper aquifer wells yielded few consistent patterns. For most of the major ions, and for TDS, alkalinity and DOC, the greatest mean concentrations were observed at far-field wells. Some exceptions are as follows:

Parameter	1981 Control Mean	1981 Near-Field Mean	1981 Far-Field Mean
Calcium	85	51	60
Nitrate	0.5	0.1	0.1
Fluoride	0.3	1.8	0.3
Silica	28	27	23

The 1981 maximum concentrations in the upper aquifer were observed at control or far-field stations. Increased concentrations of most major inorganic ions in near-field wells relative to unaffected areas were not observed during 1981. Trace constituents were fairly uniform among the control, near-field, and far-field station groups. Most of the trace constituents of importance (arsenic, selenium, boron, molybdenum, and lithium) exhibited concentrations in 1981 similar to those observed in 1980. Mean mercury levels were increased over 1980; however, it has been recently determined that the July-September mercury data may be questionable due to a problem with an analytical standard. During this period concentrations greater than 0.5 ppb were reported in some

samples. More recent samples are commonly less than 0.03 ppb. The data base will be corrected as necessary when the evaluation of this situation is completed.

c. Statistical Analysis - The MANOVA for selected upper aquifer water quality parameters indicated significant variability for most constituents (at the .05 significance level) for all parameters except pH, fluoride, chloride, and bicarbonate) for the area main effect. Significant variability for the year main effect was noted only for pH, magnesium, sodium, and marginally for chloride:

	Probability > F		
Parameter	Area	Year	Area Year
TDS	.0001	.5119	.5321
Conductivity	.0001	.3788	.3464
pH	.0634	.0001	.1006
Alkalinity	.0098	.3326	.7603
Calcium	.0001	.1379	.7716
Magnesium	.0001	.0008	.5801
Sodium	.0017	.0118	.8825
Fluoride	.1574	.0119	.7564
Chloride	.1739	.0422	.7031
Bicarbonate	.0555	.0876	.4059
Sulfate	.0001	.0782	.6077

The interaction term (area x year) was not significant for any of the constituents. This indicates a lack of change in the relative water quality at control, near-field, and far-field wells over time, although the variability among station types and years is highly significant for some constituents.

The evaluation of overall year and area (station type) effects was accomplished using the Hotelling-Lawley trace, Piffai's trace, Wilks' Criterion, and Roy's Maximum Root Criterion (Appendix 5-1.6). The first three of these analyses indicated highly significant differences for both the area and year main

effects. For the Roy's Maximum Root Criterion, the F statistic and probability values could not be estimated, indicating that certain constituents were very different from the others. For example, only fluoride and chloride were very nonsignificant for the area (station type) main effect, and pH and magnesium exhibited a much greater level of significance than the other constituents in regard to year main-effect.

The Duncan's Multiple Range Test was used to examine the nature and significance of differences in mean concentrations over time (year) and space (control, near-field, and far-field). Examination of spatial differences indicated that there are no significant differences between control and near-field means for conductivity, alkalinity, and sodium. There were no significant differences between near-field and far-field means for sodium. (Constituents with nonsignificant variability for the area [station type] main-effect were not considered in the Duncan's evaluation).

The Duncan's Multiple Range Test evaluation of differences among years gave the following results (only those constituents with significant variability for the year main effect in the MANOVA were considered):

Parameter	Years Significantly Different Than 1981
pH	1975, 1976
Sodium	1975, 1976
Chloride	1975, 1976
Magnesium	None

The means estimated for these parameters are as follows:

	Mean					
Parameter	1975	1976	1978	1979	1980	1981
pH	6.8	6.9	7.4	8.0	7.9	8.0
Magnesium	65	63	88	79	92	82
Sodium	299	325	222	205	200	194
Chloride	17	18	7	13	14	11

These means show the general increase in pH in the upper aquifer since the baseline and the decrease in sodium and chloride concentrations since then. Recent years data have been very stable for these constituents. The changes in mean concentrations over time for magnesium and chloride are not significant.

The MANOVA variance analyses, and the Duncan's Multiple Range Test indicate that although certain constituents vary significantly in time and space, the general pattern of water quality has not changed appreciably over time. Impact-related changes are not apparent from this analysis.

4. Lower Aquifer

Lower aquifer data (collected only at the far-field wells for the dewatering/reinjection/discharge program) consisted of water level measurements. In general, mean water levels in the lower aquifer have generally increased since the baseline period:

	1974	1975	1978	1979	1980	1981
Mean water level (feet)	322.5	315.4	375.4	375.6	295.2	266.6
Max. water level (feet)	322.5	732.2	376.4	375.9	375.0	374.1
Min. water level (feet)	322.5	102.6	373.3	375.1	138.1	138.0
Number of observations	1	212	61	5	66	44

Some of the variation shown here is due to different wells being sampled in various years and the subsequent different influences of location and topography factors on the depth-to-water data. The water levels have been very uniform over the last two years of record for the lower aquifer, indicating an absence of influence from the continuing reinjection operations.

5.2 MIS Modular Development Area

A. Objectives and Methods

The monitoring of the MIS Modular Development Area is designed to detect and evaluate the effects of the MIS retorts on deep aquifers and the effects of surface operations and facilities on surface streams and alluvial aquifers. Monitoring sites include surface streams, alluvial and deep-aquifer wells, process water ponds, leak detection systems, and erosion/sedimentation stations. Sampling methods are as described in previous reports.

Stations included in the MIS Modular Development Area monitoring program are as follows (RBOSC, 1981):

Station Class	Station and Identification	
Type I Control	Streams	
	B-USGS	C-USGS
	Springs and Seeps	
	SPG-3	SPG-8
	SPG-4	SPG-14
	SPG-5	SPG-MILL
	Alluvial Aquifer	
	GS-S7	GS-S8
	Deep Aquifer	
	GS-10U	GS-15L
	GS-15U	CE-708U
	GS-9U	
	Erosion & Sedimentation	
	YES-1A	YES-3

Type II
Near-Field

Streams

D-USGS
YCULDIS
YSEOFL
YMET3
YBOXFL

Impoundments and Leak Detection System

YER Pond
YWR Pond
YERO Pond
YWRO Pond
YJEF Pond
YSW 1-7

YLEACH-1
YPZR 1-4

Alluvial Aquifer

GS-S25
GS-S26
GS-S27
GS-S27A

Deep Aquifer

CE-709U
GS-MDP 2CU
CE-702U
CE-705AU

Erosion & Sedimentation

YES-4
YES-5
YES-6
YES-7
YES-8

Type III
Far-Field

Streams

F-USGS

YUPRYEL

Alluvial Aquifer

GS-S11
GS-S11A
GS-S24

Deep Aquifer

GS-M2U
GS-M3U
GS-M5U

Erosion & Sedimentation

YES-9
YES-10
YES-11

B. Results and Discussion

Temporal and spatial hydrologic variations have been examined for the MIS program element, using data from stations listed above. Where possible, univariate statistics for 1981 were compared with similar statistics for 1980 and 1976. Spatial variations were evaluated by comparing control, near-field, and far-field univariate statistics for surface streams, alluvial aquifers, and upper aquifer wells. An analysis of variance procedure was used to test the significance of observed variations and space-time interactions.

1. Impoundments and Leak Detection System

No water quality samples were collected from the east or west runoff ponds during 1981. The Jeffrey Pond (YJEF Pond) and West Retention Pond (YWRPOND) received water from the mine sumps and exhibited the water quality of area upper aquifer water. These data are presented in the discussion of the dewatering/reinjection/discharge program (Section 5.1) and will not be repeated here. Field and water quality data for impoundments and leak detection systems are presented in Appendices 5-2.1 and 5-2.2, respectively.

The East Retention Pond (YERPOND) is located adjecent to the MIS surface process area and receives runoff, spills, etc. from that area. Changes in mean water quality of the East Retention Pond in 1981 (Table 5-9) as compared to 1980 reflect increased production activities in 1981:

Parameter	1981 Mean	1980 Mean
TDS	2936	1145
Alkalinity	884	245
Magnesium	67	38
Sodium	1028	257
Bicarbonate	552	140
Chloride	202	133
Sulfate	1349	432
Ammonia	7.7	0.3
DOC	12.4	79.7

Table 5-9. Summary of Water Quality Data for East Retention Pond (YERPOND), 1981

TYPE=DEVELOPMENT ACTIVITIES MONITORING SYSTEM STATION = YERPOND REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	11	9.12	0.58	10.50	8.50	8.50	10.50
CONDUCTIVITY	11	3315.91	1501.26	6400.00	2200.00	2200.00	6400.00
TOT DIS SOLIDS	7	2935.57	1654.35	5011.00	704.00	704.00	5011.00
ALKALINITY	8	884.38	727.18	2449.00	395.00	395.00	2449.00
CALCIUM	9	17.67	8.74	28.00	4.00	4.00	28.00
MAGNESIUM	7	66.71	27.08	86.00	7.00	7.00	86.00
POTASSIUM	7	5.03	3.48	10.50	0.70	0.70	10.50
SODIUM	9	1027.78	690.01	2180.00	390.00	390.00	2180.00
BICARBONATE	10	552.40	205.62	879.00	315.00	315.00	879.00
CARBONATE	9	38.68	57.70	164.00	0.13	0.13	164.00
CHLORIDE	9	201.90	266.55	728.00	1.69	1.69	728.00
NITRATE	6	0.82	0.83	1.90	0.10	0.10	1.90
SULFATE	9	1349.22	639.45	2380.00	660.00	660.00	2380.00
FLUORIDE	7	0.88	0.64	1.86	0.29	0.29	1.86
AMMONIA	6	7.72	5.17	14.97	0.64	0.64	14.97
PHOSPHATE	7	0.20	0.10	0.30	0.03	0.03	0.30
BORON	7	0.27	0.14	0.51	0.11	0.11	0.51
SILICA	7	11.71	5.44	17.00	3.00	3.00	17.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	8	12.38	6.78	21.00	0.00	0.00	21.00
ARSENIC	1	0.01	.	0.01	0.01	0.01	0.01
SELENIUM	2	0.05	0.02	0.07	0.04	0.04	0.07
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	2	0.15	0.07	0.20	0.10	0.10	0.20
MERCURY	4	1.45	1.33	3.40	0.60	0.60	3.40
ALUMINUM	1	0.20	.	0.20	0.20	0.20	0.20
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	1	0.06	.	0.06	0.06	0.06	0.06
LITHIUM	3	0.23	0.02	0.24	0.21	0.21	0.24
MANGANESE	2	0.06	0.01	0.07	0.06	0.06	0.07
NICKEL	0	.	.	.	.	.	.
STRONTIUM	3	3.21	1.81	4.71	1.20	1.20	4.71
TITANIUM	0	.	.	.	.	.	.
ZINC	2	0.02	0.02	0.04	0.01	0.01	0.04
ZIRCONIUM	0	.	.	.	.	.	.

Water was discharged from the East Retention Pond for six days in March 1981. Approximately 2 million gallons were discharged. The pH of the East Retention Pond was relatively stable during 1981, varying from about 8.5 to 9. The conductivity was 2000-3000 micromhos/cm during the first half of 1981 but increased during the second half of 1981 to over 6000 micromhos/cm as a result of Retort 1 operations (Figure 5-6). There was no discharge of this higher conductivity water.

The water quality of eight of the evaporation ponds (1, 2, 3, 4, 5, 6, 7, and 9) was sampled during 1981 (Appendix 5-2.2). Ponds 4 and 7 contained sour water while the others contained scrubber blowdown water. The water quality in many of the ponds was quite variable over the year due to the variations in operations during 1981.

Water was detected during 1981 in piezometers 1 and 4 located adjacent to the evaporation ponds. Examination of the water quality data for piezometer 4 (Table 5-10) indicated that the water was probably due to precipitation rather than pond leakage. Similar water quality was observed in piezometer 4 during 1980.

2. Springs and Seeps

Several spring and seep monitoring stations function as controls for the MIS Area Program. Water quality data from these stations are contained in Appendix 5-2.3. Mean concentrations for most major inorganics in 1981 (Table 5-11) decreased relative to 1980:

Parameter	1981 Mean	1980 Mean
TDS	1031	1142
Alkalinity	468	535
Calcium	110	119
Magnesium	75	91
Sodium	135	151
Sulfate	383	459
DOC	8	54

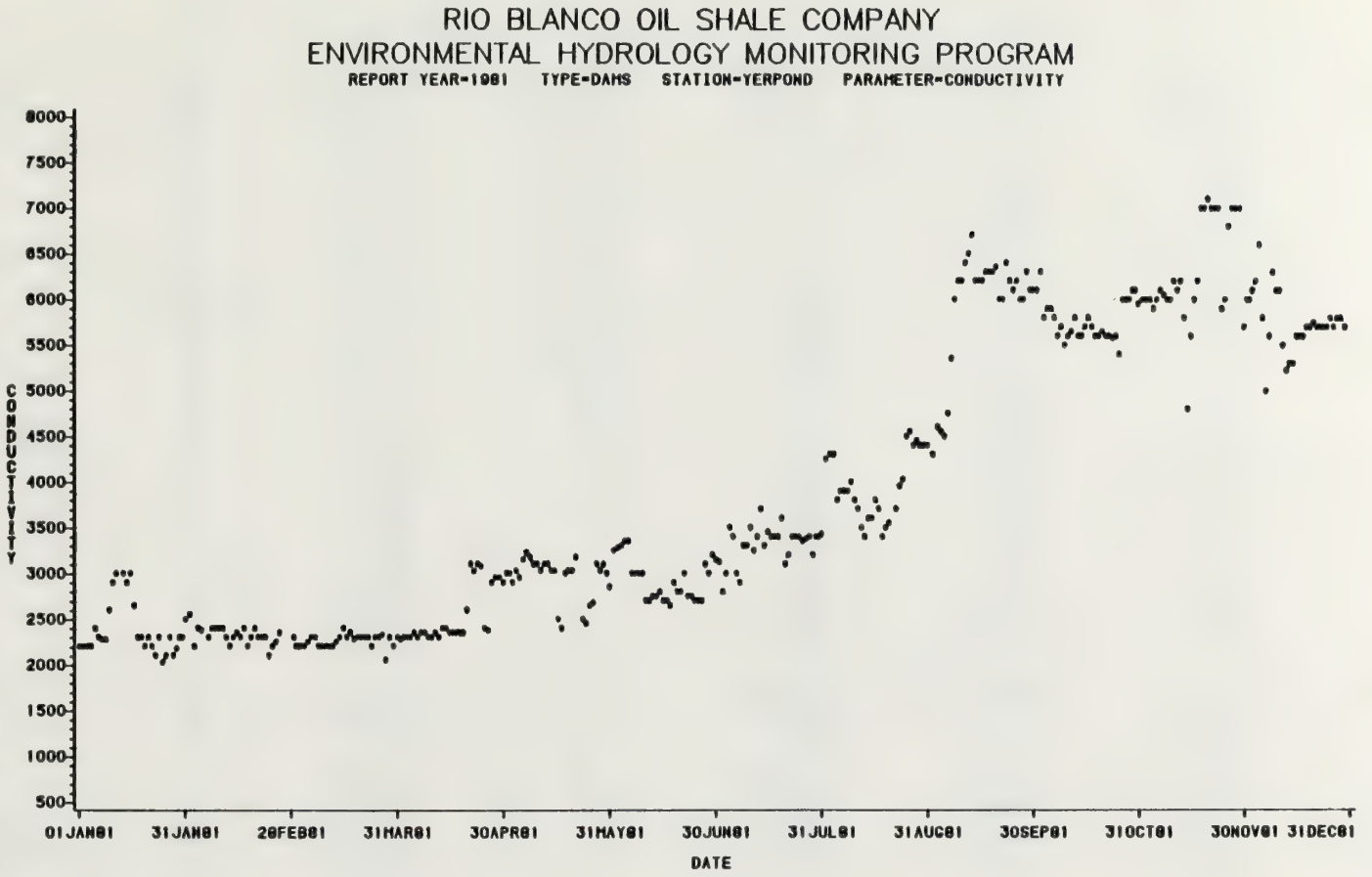


Figure 5-6. Conductivity (micromhos per cm) of East Retention Pond (YERPOND) During 1981

Table 5-10. Summary of Water Quality Data for Piezometer YPZR-4, 1981

TYPE=DEVELOPMENT ACTIVITIES MONITORING SYSTEM STATION = YPZR-4 REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	1	7.50	.	7.50	7.50	7.50	7.50
CONDUCTIVITY	1	1500.00	.	1500.00	1500.00	1500.00	1500.00
TOT DIS SOLIDS	1	1268.00	.	1268.00	1268.00	1268.00	1268.00
ALKALINITY	1	509.00	.	509.00	509.00	509.00	509.00
CALCIUM	1	150.00	.	150.00	150.00	150.00	150.00
MAGNESIUM	1	90.00	.	90.00	90.00	90.00	90.00
POTASSIUM	1	2.40	.	2.40	2.40	2.40	2.40
SODIUM	1	120.00	.	120.00	120.00	120.00	120.00
BICARBONATE	1	598.00	.	598.00	598.00	598.00	598.00
CARBONATE	0	.	.	.	.	.	.
CHLORIDE	1	25.20	.	25.20	25.20	25.20	25.20
NITRATE	1	1.20	.	1.20	1.20	1.20	1.20
SULFATE	1	458.00	.	458.00	458.00	458.00	458.00
FLUORIDE	1	0.10	.	0.10	0.10	0.10	0.10
AMMONIA	1	2.27	.	2.27	2.27	2.27	2.27
PHOSPHATE	1	0.14	.	0.14	0.14	0.14	0.14
BORON	1	0.61	.	0.61	0.61	0.61	0.61
SILICA	1	21.00	.	21.00	21.00	21.00	21.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	1	18.00	.	18.00	18.00	18.00	18.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	0	.	.	.	.	.	.
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	0	.	.	.	.	.	.
MANGANESE	0	.	.	.	.	.	.
NICKEL	0	.	.	.	.	.	.
STRONTIUM	0	.	.	.	.	.	.
TITANIUM	0	.	.	.	.	.	.
ZINC	0	.	.	.	.	.	.
ZIRCONIUM	0	.	.	.	.	.	.

Table 5-11. Summary of Water Quality Data for Springs and Seeps, MIS Monitoring Program, 1981

TYPE=SEEP AREA=CONTROL REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	20	7.92	0.36	8.90	7.20	7.20	8.86
CONDUCTIVITY	20	1243.25	350.55	2100.00	900.00	902.50	2087.50
TOT DIS SOLIDS	7	1030.71	317.40	1626.00	754.00	754.00	1626.00
ALKALINITY	10	468.00	143.48	694.00	342.00	342.00	694.00
CALCIUM	7	110.00	17.08	140.00	85.00	85.00	140.00
MAGNESIUM	7	74.71	22.71	120.00	56.00	56.00	120.00
POTASSIUM	7	1.74	0.53	2.50	0.88	0.88	2.50
SODIUM	7	135.43	70.18	240.00	77.00	77.00	240.00
BICARBONATE	10	545.00	175.85	821.00	379.00	379.00	821.00
CARBONATE	1	1.21	.	1.21	1.21	1.21	1.21
CHLORIDE	7	19.08	12.59	43.60	7.95	7.95	43.60
NITRATE	6	0.62	0.45	1.20	0.20	0.20	1.20
SULFATE	7	382.71	119.16	611.00	253.00	253.00	611.00
FLUORIDE	7	0.30	0.08	0.37	0.17	0.17	0.37
AMMONIA	3	0.84	0.55	1.40	0.31	0.31	1.40
PHOSPHATE	5	0.15	0.15	0.42	0.07	0.07	0.42
BORON	7	0.30	0.14	0.45	0.13	0.13	0.45
SILICA	7	20.43	4.20	26.00	15.00	15.00	26.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	16	8.06	4.22	16.00	3.00	3.00	16.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	0	.	.	.	.	.	.
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	5	0.04	0.03	0.07	0.01	0.01	0.07
MANGANESE	4	0.24	0.33	0.73	0.03	0.03	0.73
NICKEL	0	.	.	.	.	.	.
STRONTIUM	5	1.66	0.47	2.28	1.13	1.13	2.28
TITANIUM	0	.	.	.	.	.	.
ZINC	2	0.02	0.01	0.03	0.01	0.01	0.03
ZIRCONIUM	0	.	.	.	.	.	.

A similar pattern of decreased maximum concentrations for this group of monitoring stations was also observed. The 1981 maximum TDS (1626 mg/l) and alkalinity (694 mg/l) levels were observed at SPG-14 and SPG-MILL (Miller's Spring), respectively.

3. Streams

Several near-field stream stations were monitored to examine the effects of MIS operations. Physical and water quality data from these stations are contained in Appendix 5-2.4. These stations include the following:

- YBOXFL - on Box Elder Gulch
- YMET3 - on Corral Gulch below the confluence with Box Elder Gulch
- YSEOFL - on Corral Gulch approximately 1.5 miles below YMET3

The 1981 data for conductivity at YMET3 and flow and conductivity at YSEOFL are summarized in Figures 5-7, 5-8 and 5-9.

The 1981 mean water quality observed at YBOXFL and YMET3 was very similar. The concentrations of most major inorganic constituents increased appreciably between YMET3 the YSEOFL, located downstream (Tables 5-12 and 5-13):

Parameter	YMET3 1981 Mean	SEOFL 1981 Mean
TDS	1043	1496
Alkalinity	465	504
Magnesium	68	92
Sodium	160	273
Bicarbonate	539	563
Chloride	10	66
Sulfate	337	624
DOC	4	10

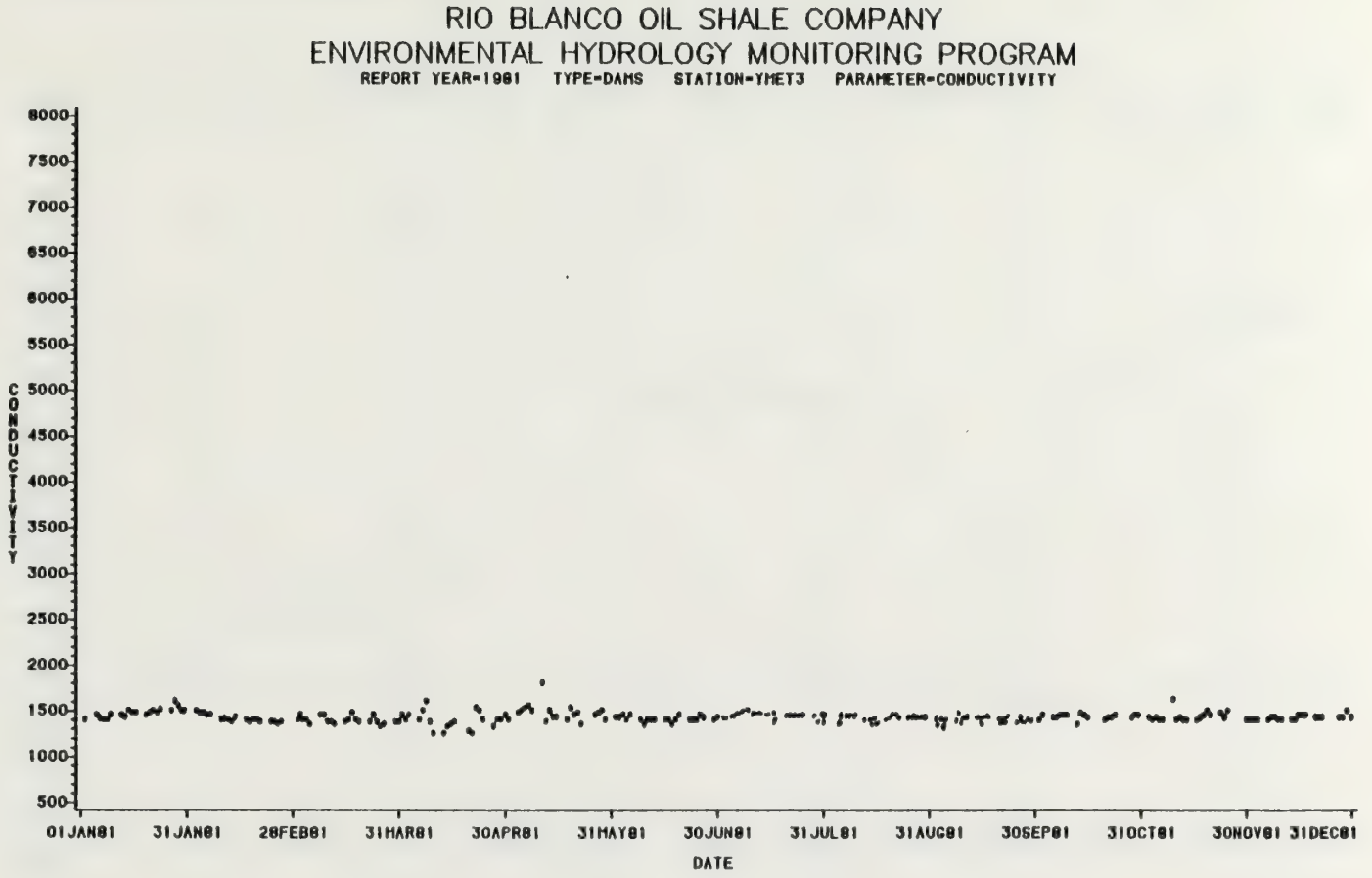


Figure 5-7. Conductivity (micromhos per cm) YMET3 Stream Station During 1981

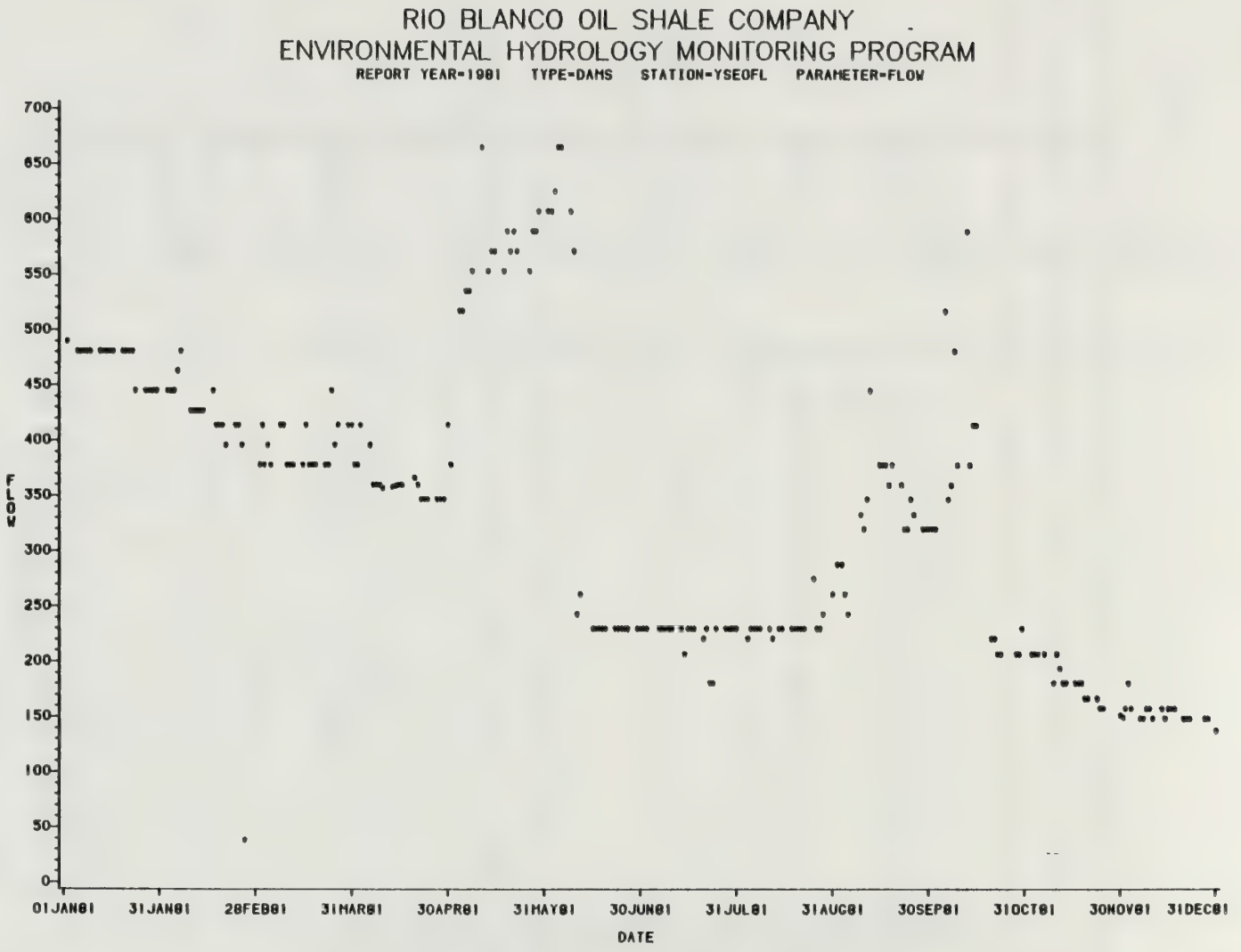


Figure 5-8. Flow (gpm) YSEOFL Stream Station During 1981

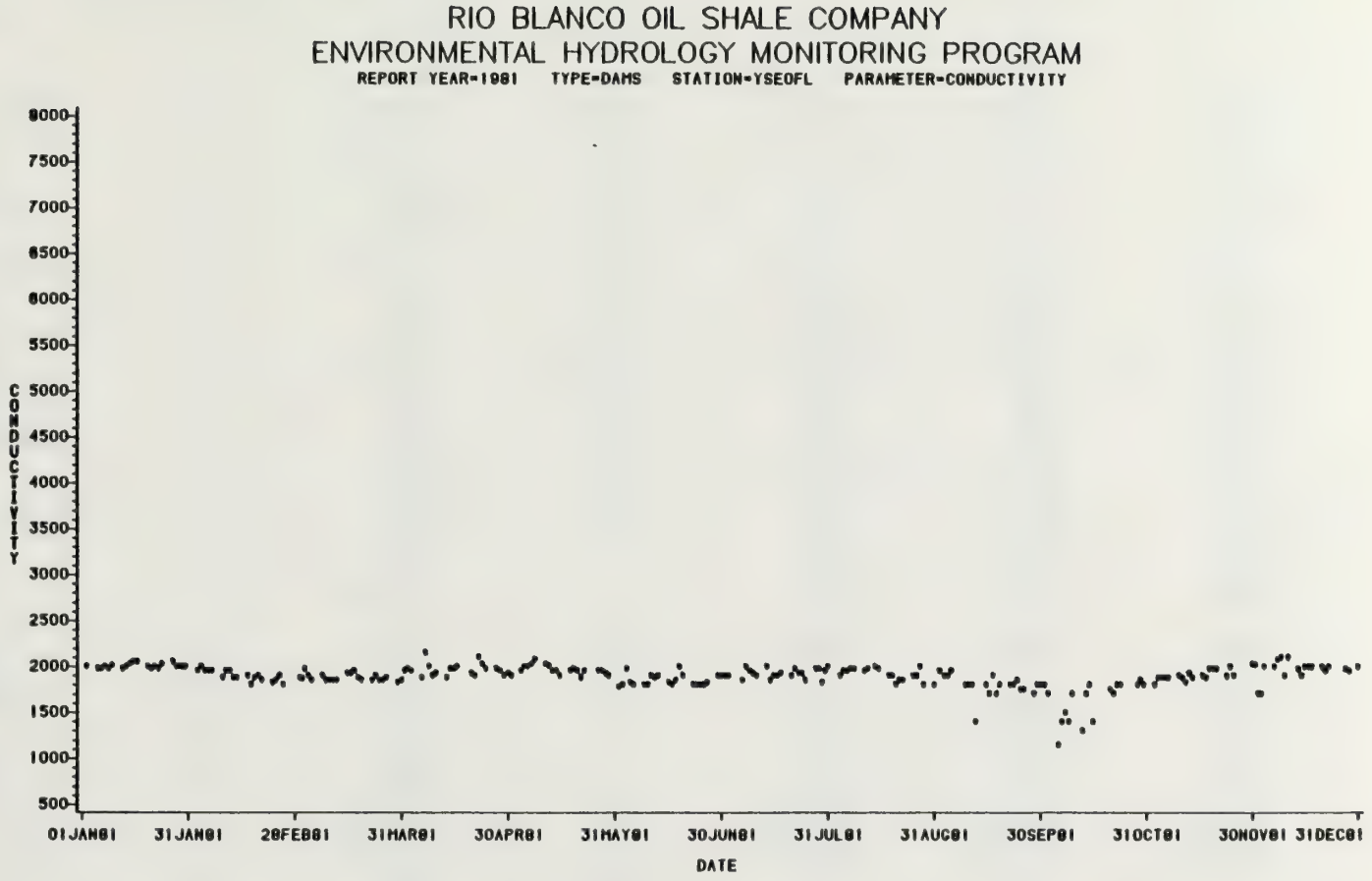


Figure 5-9. Conductivity (micromhos per cm) YSEOFL Stream Station During 1981

Table 5-12. Summary of Water Quality Data for Stream Station YMET3, 1981

TYPE=DEVELOPMENT ACTIVITIES MONITORING SYSTEM STATION = YMET3 REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	5	7.50	0.21	7.80	7.20	7.20	7.80
CONDUCTIVITY	5	1380.00	164.32	1500.00	1100.00	1100.00	1500.00
TOT DIS SOLIDS	1	1043.00	.	1043.00	1043.00	1043.00	1043.00
ALKALINITY	3	465.33	60.93	502.00	395.00	395.00	502.00
CALCIUM	1	78.00	.	78.00	78.00	78.00	78.00
MAGNESIUM	1	68.00	.	68.00	68.00	68.00	68.00
POTASSIUM	1	1.15	.	1.15	1.15	1.15	1.15
SODIUM	1	160.00	.	160.00	160.00	160.00	160.00
BICARBONATE	3	539.00	72.17	587.00	456.00	456.00	587.00
CARBONATE	0	.	.	.	.	.	.
CHLORIDE	1	10.20	.	10.20	10.20	10.20	10.20
NITRATE	0	.	.	.	.	.	.
SULFATE	1	337.00	.	337.00	337.00	337.00	337.00
FLUORIDE	1	0.63	.	0.63	0.63	0.63	0.63
AMMONIA	1	0.86	.	0.86	0.86	0.86	0.86
PHOSPHATE	1	0.10	.	0.10	0.10	0.10	0.10
BORON	1	0.98	.	0.98	0.98	0.98	0.98
SILICA	1	24.00	.	24.00	24.00	24.00	24.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	1	4.00	.	4.00	4.00	4.00	4.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	1	0.60	.	0.60	0.60	0.60	0.60
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	0	.	.	.	.	.	.
MANGANESE	0	.	.	.	.	.	.
NICKEL	0	.	.	.	.	.	.
STRONTIUM	0	.	.	.	.	.	.
TITANIUM	0	.	.	.	.	.	.
ZINC	0	.	.	.	.	.	.
ZIRCONIUM	0	.	.	.	.	.	.

Table 5-13. Summary of Water Quality Data for Stream Station YSEOFL, 1981

TYPE=DEVELOPMENT ACTIVITIES MONITORING SYSTEM STATION = YSEOFL REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	3	7.90	0.20	8.10	7.70	7.70	8.10
CONDUCTIVITY	3	1816.67	146.49	1925.00	1650.00	1650.00	1925.00
TOT DIS SOLIDS	3	1496.33	172.02	1680.00	1339.00	1339.00	1680.00
ALKALINITY	3	503.67	95.55	584.00	398.00	398.00	584.00
CALCIUM	3	72.67	40.45	104.00	27.00	27.00	104.00
MAGNESIUM	3	92.33	21.08	110.00	69.00	69.00	110.00
POTASSIUM	3	4.83	4.48	10.00	2.10	2.10	10.00
SODIUM	3	273.33	127.02	420.00	200.00	200.00	420.00
BICARBONATE	3	563.00	144.71	687.00	404.00	404.00	687.00
CARBONATE	1	2.57	.	2.57	2.57	2.57	2.57
CHLORIDE	3	65.60	75.89	153.00	16.40	16.40	153.00
NITRATE	3	0.57	0.55	1.20	0.20	0.20	1.20
SULFATE	3	624.00	135.51	778.00	523.00	523.00	778.00
FLUORIDE	3	0.30	0.20	0.45	0.07	0.07	0.45
AMMONIA	2	0.57	0.60	1.00	0.15	0.15	1.00
PHOSPHATE	3	0.17	0.08	0.26	0.10	0.10	0.26
BORON	2	0.33	0.33	0.57	0.10	0.10	0.57
SILICA	3	18.00	3.61	22.00	15.00	15.00	22.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	3	10.00	7.00	17.00	3.00	3.00	17.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	3	2.97	3.48	6.90	0.30	0.30	6.90
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	0	.	.	.	.	.	.
MANGANESE	0	.	.	.	.	.	.
NICKEL	0	.	.	.	.	.	.
STRONTIUM	0	.	.	.	.	.	.
TITANIUM	0	.	.	.	.	.	.
ZINC	0	.	.	.	.	.	.
ZIRCONIUM	0	.	.	.	.	.	.

As can be seen, most of the increase is due to sodium and sulfate concentrations, with magnesium, bicarbonate, and chloride concentrations contributing to a lesser extent.

Final 1981 USGS data on water chemistry and daily values for conductivity, temperature, and sediment were not available when this report was prepared. Final data on mean daily flows at the USGS gaging sites were available and are summarized in Table 5-14. However, these data were not available in computer-usable form and thus statisitical analysis was not conducted for this report.

The flow data presented in Table 5-14 indicate that Tract C-a was a net producer of surface flows (outflow exceeded inflow) during every month of the 1981 water year. This water balance result is comparable to that observed in pre-1978 data, prior to discharge operations from dewatering.

4. Alluvial Aquifers

a. Field Data - Alluvial aquifer wells GS-S7, and GS-S8 function as controls for the MIS Area hydrology monitoring program. These wells exhibited lower mean water levels in 1981 than were observed in 1979 and 1980, (see Figure 5-10 for GS-S8 water levels). Water temperatures and field measurements of pH during 1981 were comparable to previous years. The 1981 specific conductance for GS-S8 (Figure 5-11) was generally lower than was observed for the previous four years (Appendix 5-2.5).

The near-field alluvial wells for the MIS program were usually dry during 1979 and 1980. The 1981 water level data for near-field well GS-S27 are shown in Figure 5-12. The 1981 mean water temperature and pH observations for the near-field wells were comparable to 1977 and 1978 data while mean field specific conductance in 1981 (1489 micromhos/cm) was greater than in earlier years (1260-1275 micromhos/cm; see Figure 5-13 for 1981 specific conductance at GS-S27).

The mean specific conductance was also greater in 1981 at far-field alluvial stations than that observed in earlier years. The 1981 field pH and water

Table 5-14. Summary of Flows at USGS Gaging Stations, 1981 Water Year

Month / Station	Total Flow (acre-feet)											
	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.
A - Dry Fork	-0-	-0-	-0-	-0-	-0-	-0-	-0-	.05	.02	.24	.06	.52
C - Box Elder - West	.38	-0-	-0-	-0-	.01	.02	-0-	-0-	-0-	.40	.49	5.59
B - Corral Gulch - West	5.22	3.46	2.65	2.15	-0-	.06	.29	2.30	1.63	3.17	5.97	6.04
E - Box Elder Tributary	-0-	-0-	-0-	-0-	.51	.17	-0-	.17	.85	.76	.08	1.56
Total Inflow	5.60	3.46	2.65	2.15	.52	.25	.29	2.52	2.50	4.57	6.60	13.17
D - Corral Gulch - East (Total outflow)	14.14	10.23	19.03	12.15	10.74	12.38	10.66	11.63	14.06	21.93	15.09	20.42
Outflow - Inflow	8.54	6.77	16.38	10.00	10.22	12.13	10.37	9.11	11.56	17.36	8.49	6.71
F - Yellow Creek	39.73	38.27	39.83	38.77	31.36	38.77	33.28	30.05	20.62	15.60	13.50	13.64

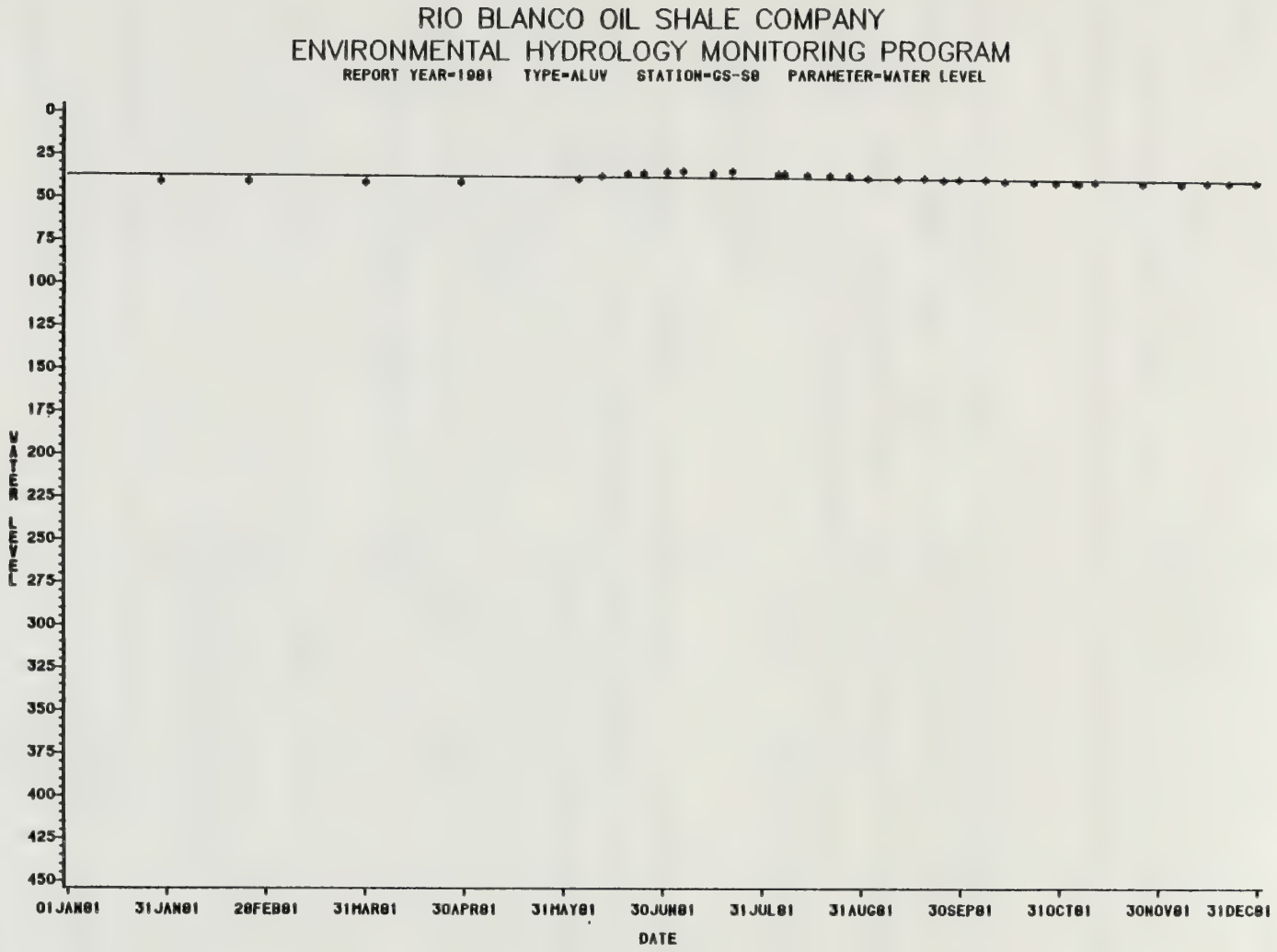


Figure 5-10. Water Level (Depth to Water, Feet) of Alluvial Well GS-S8 During 1981

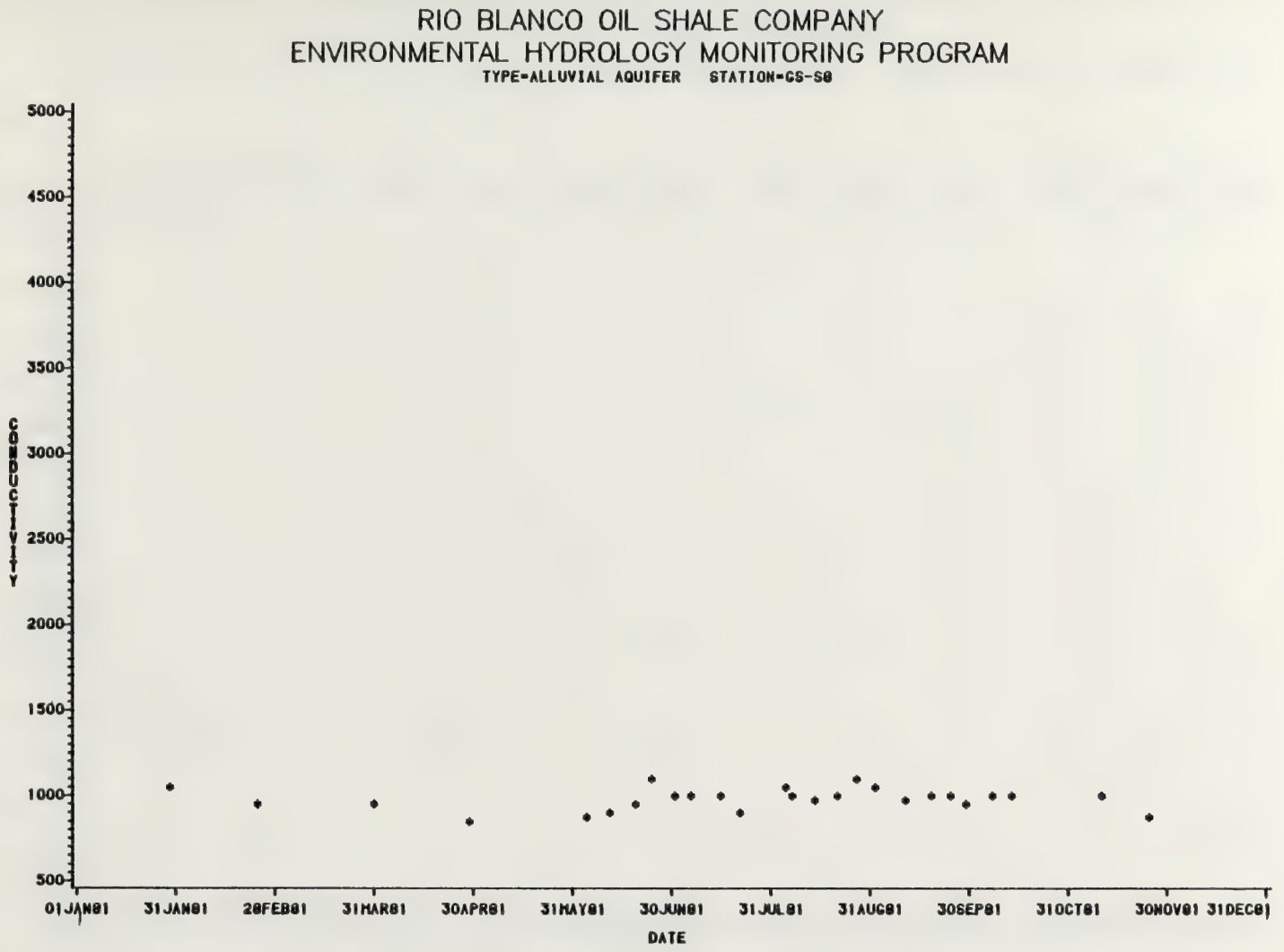


Figure 5-11. Conductivity (micromhos per cm) in Alluvial Well GS-S8 During 1981

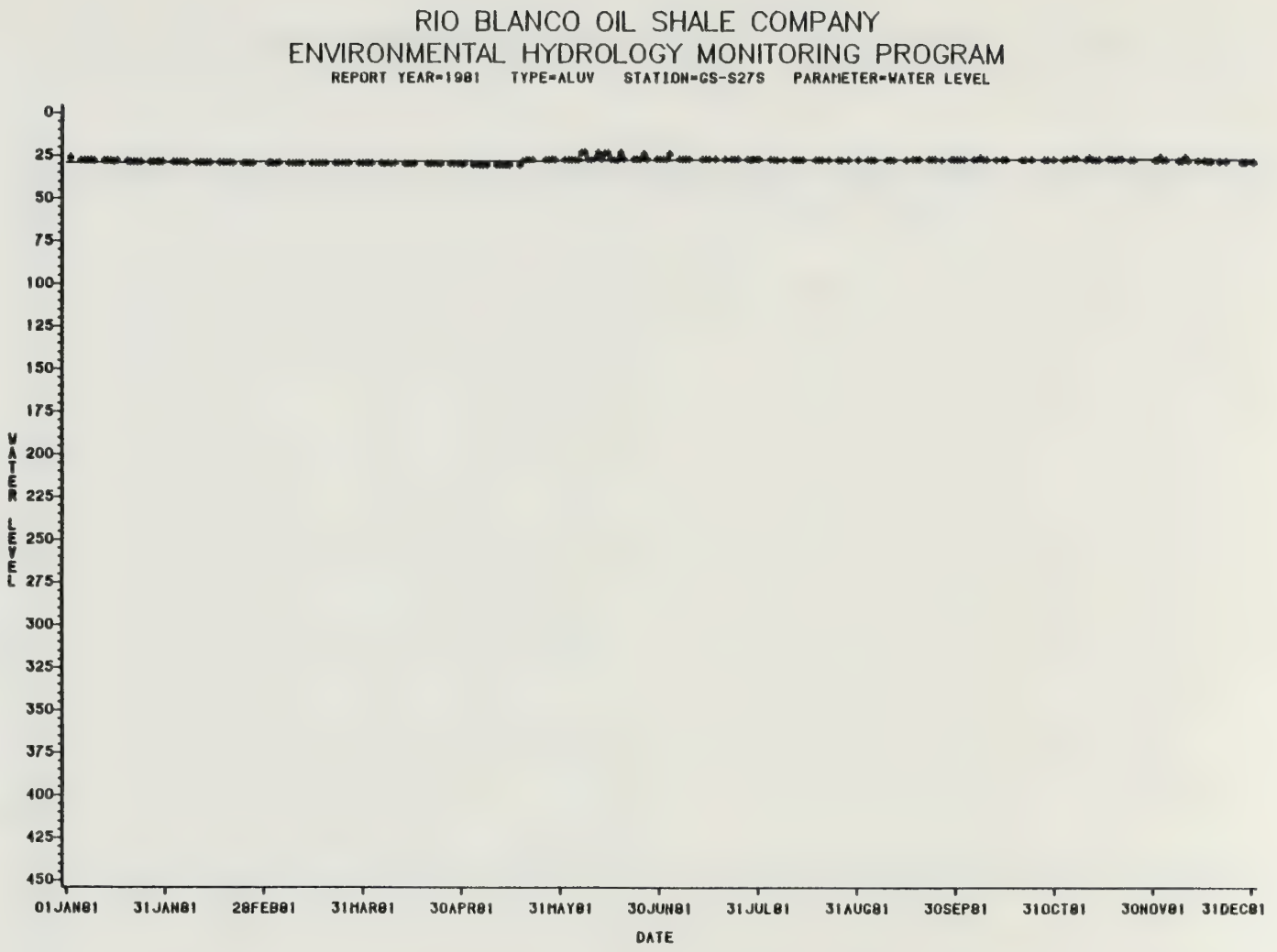


Figure 5-12. Water Level (Depth to Water, Feet) in Alluvial Well GS-S27S During 1981

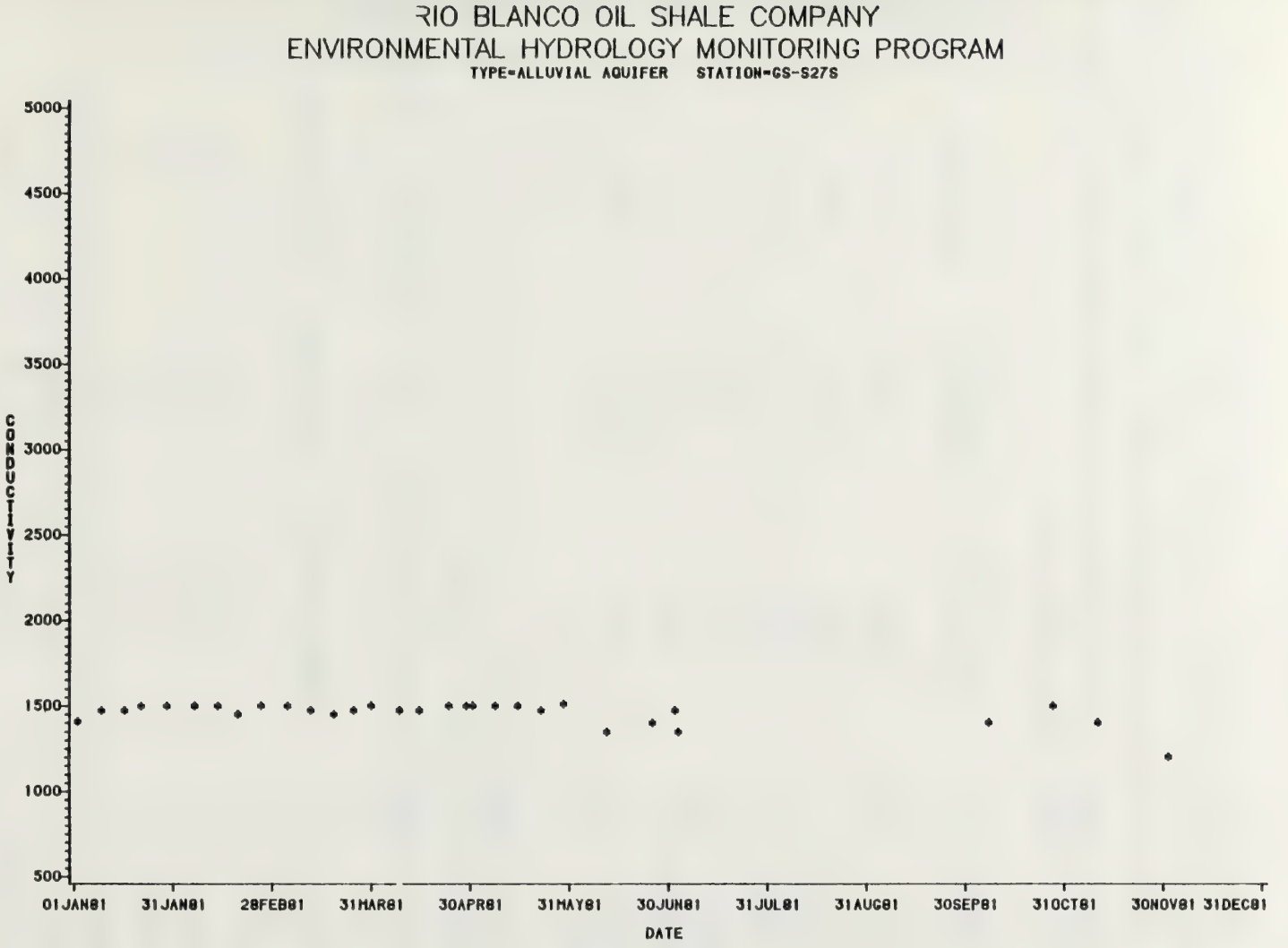


Figure 5-13. Conductivity (micromhos per cm) in Alluvial well GS-S27S During 1981

temperature data are comparable to observations from previous years. Mean water levels at the far-field wells during 1981 were similar to mean observations since 1977 (see Figures 5-14 and 5-15 for 1981 GS-S24 water level and specific conductance data).

b. Water Quality Data - Water quality data for alluvial wells is presented in Appendix 5-2.6. The general water quality (TDS, alkalinity, and DOC) at alluvial control wells has been fairly stable since the baseline period (1976). Most of the variability in mean concentrations is due to 1981 calcium and sulfate levels (Table 5-15):

Parameter	1981 Mean	1980 Mean	1976 Mean
TDS	806	792	776
Alkalinity	387	386	383
Calcium	104	87	86
Magnesium	61	60	49
Sodium	89	86	119
Bicarbonate	450	454	425
Sulfate	310	253	266
DOC	9	6	8

Yearly maximum concentrations at alluvial control wells for the MIS program have been similarly stable. However, the baseline (1976) maxima were appreciably greater than more recent data for TDS, alkalinity, and sodium:

Parameter	1981 Maximum	1980 Maximum	1976 Maximum
TDS	901	904	945
Alkalinity	406	440	880
Calcium	115	116	120
Magnesium	68	71	70
Sodium	100	115	180
Bicarbonate	469	519	490
Sulfate	391	354	350
DOC	20	20	11

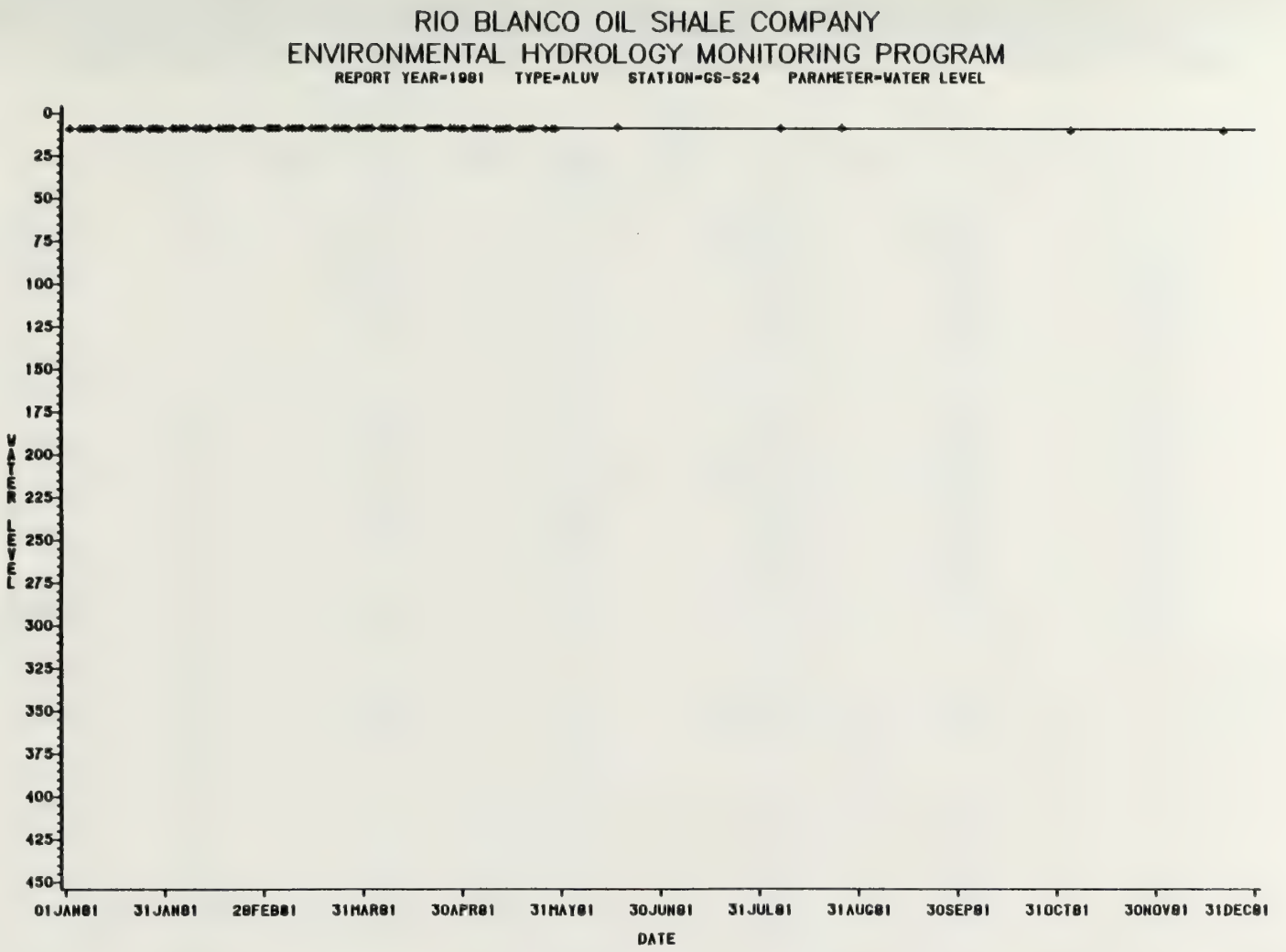


Figure 5-14. Water Level (Depth to Water, Feet) in Alluvial Well GS-S24 During 1981

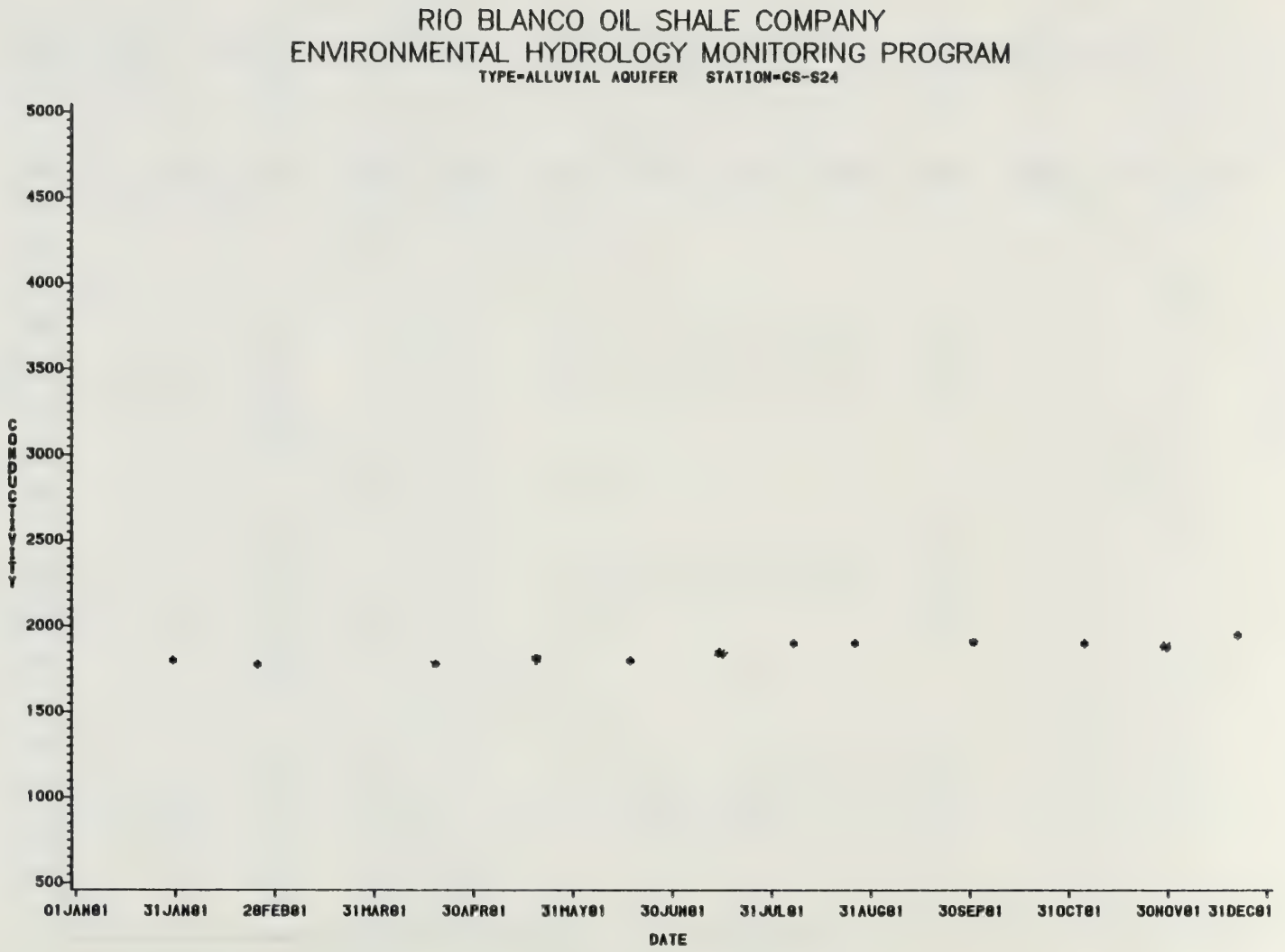


Figure 5-15. Conductivity (micromhos per cm) in Alluvial Well GS-S24 During 1981

Table 5-15. Summary of Water Quality Data for Alluvial Control Wells, MIS Monitoring Program, 1981

TYPE=ALUV AREA=CONTROL REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	7	7.53	0.19	7.70	7.20	7.20	7.70
CONDUCTIVITY	7	1103.57	133.41	1225.00	850.00	850.00	1225.00
TOT DIS SOLIDS	7	806.43	67.32	901.00	728.00	728.00	901.00
ALKALINITY	7	387.43	12.61	406.00	367.00	367.00	406.00
CALCIUM	7	103.57	8.10	115.00	93.00	93.00	115.00
MAGNESIUM	7	61.29	5.38	68.00	54.00	54.00	68.00
POTASSIUM	7	1.10	0.07	1.20	0.99	0.99	1.20
SODIUM	7	89.29	10.44	100.00	77.00	77.00	100.00
BICARBONATE	7	449.86	14.31	469.00	427.00	427.00	469.00
CARBONATE	0	.	.	.	.	.	.
CHLORIDE	7	17.75	10.36	34.60	9.47	9.47	34.60
NITRATE	6	0.90	0.21	1.10	0.50	0.50	1.10
SULFATE	7	309.57	53.18	391.00	232.00	232.00	391.00
FLUORIDE	7	0.17	0.10	0.38	0.08	0.08	0.38
AMMONIA	4	0.19	0.08	0.26	0.10	0.10	0.26
PHOSPHATE	7	0.05	0.03	0.10	0.01	0.01	0.10
BORON	4	0.37	0.32	0.81	0.10	0.10	0.81
SILICA	7	20.71	1.60	23.00	18.00	18.00	23.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	7	8.86	6.39	20.00	2.00	2.00	20.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	3	1.07	0.31	1.40	0.80	0.80	1.40
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	2	0.75	0.07	0.80	0.70	0.70	0.80
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	1	0.02	.	0.02	0.02	0.02	0.02
MANGANESE	0	.	.	.	.	.	.
NICKEL	0	.	.	.	.	.	.
STRONTIUM	2	1.15	0.16	1.27	1.04	1.04	1.27
TITANIUM	0	.	.	.	.	.	.
ZINC	1	0.01	.	0.01	0.01	0.01	0.01
ZIRCONIUM	0	.	.	.	.	.	.

Near-field alluvial wells in the MIS Area monitoring program are typically dry. For example, these wells were dry in 1976 and 1980. Thus, relatively few observations of water quality were made in 1981 (Table 5-16). Because these wells only intermittently contain water, different wells are being sampled at different times. Consequently, the water quality data of the near-field wells are rather variable:

	1981		1979		1977	
Parameter	Min	Max	Min	Max	Min	Max
TDS	1108	1289	-	-	840	-
Alkalinity	509	520	478	482	420	-
Calcium	106	160	82	90	120	-
Magnesium	93	98	110	116	60	-
Sodium	130	140	138	180	130	-
Bicarbonate	598	613	584	588	505	-
Chloride	13.8	14.2	12.0	69.0	13.0	-
Sulfate	424	547	458	510	355	-
DOC	4	6	4.5	-	-	-

In a similar manner, the water quality of the far-field alluvial data set (Table 5-17) has been variable in recent years due to intermittent dry conditions in many wells. Selected years data are listed below to illustrate this variability:

	1981		1979		1977	
Parameter	Min	Max	Min	Max	Min	Max
TDS	1469	1584	1000	1270	1180	1280
Alkalinity	532	729	437	560	475	505
Calcium	120	150	84	110	42	110
Magnesium	123	160	63	184	73	130
Sodium	160	180	230	190	170	230
Bicarbonate	622	635	530	690	580	615
Chloride	17	20	14	41	13	18
Sulfate	645	746	351	961	450	490
DOC	6	32	403	66	8	12

Consistent temporal trends are not obvious in these data sets.

Table 5-16. Summary of Water Quality Data for Alluvial Near-Field Wells, MIS Monitoring Program, 1981

TYPE=ALUV AREA=NEAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	2	7.70	0.00	7.70	7.70	7.70	7.70
CONDUCTIVITY	2	1487.50	17.68	1500.00	1475.00	1475.00	1500.00
TOT DIS SOLIDS	2	1198.50	127.99	1289.00	1108.00	1108.00	1289.00
ALKALINITY	2	514.50	7.78	520.00	509.00	509.00	520.00
CALCIUM	2	133.00	38.18	160.00	106.00	106.00	160.00
MAGNESIUM	2	95.50	3.54	98.00	93.00	93.00	98.00
POTASSIUM	2	1.30	0.42	1.60	1.01	1.01	1.60
SODIUM	2	135.00	7.07	140.00	130.00	130.00	140.00
BICARBONATE	2	605.50	10.61	613.00	598.00	598.00	613.00
CARBONATE	0	.	.	.	.	.	.
CHLORIDE	2	14.00	0.28	14.20	13.80	13.80	14.20
NITRATE	2	0.15	0.07	0.20	0.10	0.10	0.20
SULFATE	2	485.50	86.97	547.00	424.00	424.00	547.00
FLUORIDE	2	0.27	0.09	0.34	0.21	0.21	0.34
AMMONIA	2	0.19	0.21	0.34	0.04	0.04	0.34
PHOSPHATE	2	0.06	0.04	0.09	0.04	0.04	0.09
BORON	1	0.28	.	0.28	0.28	0.28	0.28
SILICA	2	15.50	7.78	21.00	10.00	10.00	21.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	2	5.00	1.41	6.00	4.00	4.00	6.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	1	0.10	.	0.10	0.10	0.10	0.10
MERCURY	1	1.50	.	1.50	1.50	1.50	1.50
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	0	.	.	.	.	.	.
MANGANESE	0	.	.	.	.	.	.
NICKEL	0	.	.	.	.	.	.
STRONTIUM	0	.	.	.	.	.	.
TITANIUM	0	.	.	.	.	.	.
ZINC	0	.	.	.	.	.	.
ZIRCONIUM	0	.	.	.	.	.	.

Table 5-17. Summary of Water Quality Data for Alluvial Far-Field Wells, MIS Monitoring Program, 1981

TYPE=ALUV AREA=FAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	3	7.40	0.36	7.70	7.00	7.00	7.70
CONDUCTIVITY	3	1891.67	87.80	1975.00	1800.00	1800.00	1975.00
TOT DIS SOLIDS	3	1508.33	65.55	1584.00	1469.00	1469.00	1584.00
ALKALINITY	3	598.33	113.17	729.00	532.00	532.00	729.00
CALCIUM	3	132.67	15.53	150.00	120.00	120.00	150.00
MAGNESIUM	3	137.67	19.66	160.00	123.00	123.00	160.00
POTASSIUM	3	2.00	0.34	2.40	1.78	1.78	2.40
SODIUM	3	170.00	10.00	180.00	160.00	160.00	180.00
BICARBONATE	3	627.67	6.66	635.00	622.00	622.00	635.00
CARBONATE	1	1.00	.	1.00	1.00	1.00	1.00
CHLORIDE	3	18.93	1.69	20.10	17.00	17.00	20.10
NITRATE	3	0.80	0.56	1.30	0.20	0.20	1.30
SULFATE	3	688.33	52.00	746.00	645.00	645.00	746.00
FLUORIDE	3	0.18	0.12	0.32	0.11	0.11	0.32
AMMONIA	3	0.72	0.73	1.50	0.06	0.06	1.50
PHOSPHATE	3	0.05	0.05	0.10	0.01	0.01	0.10
BORON	3	0.74	1.01	1.90	0.14	0.14	1.90
SILICA	3	20.33	1.15	21.00	19.00	19.00	21.00
IRON	1	0.05	.	0.05	0.05	0.05	0.05
DIS ORG CARBON	3	16.00	14.00	32.00	6.00	6.00	32.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	1	0.10	.	0.10	0.10	0.10	0.10
MERCURY	0	.	.	.	.	.	.
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	1	0.90	.	0.90	0.90	0.90	0.90
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	1	0.14	.	0.14	0.14	0.14	0.14
COPPER	1	0.02	.	0.02	0.02	0.02	0.02
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	1	0.03	.	0.03	0.03	0.03	0.03
MANGANESE	0	.	.	.	.	.	.
NICKEL	0	.	.	.	.	.	.
STRONTIUM	1	2.64	.	2.64	2.64	2.64	2.64
TITANIUM	0	.	.	.	.	.	.
ZINC	1	0.05	.	0.05	0.05	0.05	0.05
ZIRCONIUM	0	.	.	.	.	.	.

The concentrations for most major inorganic constituents in the MIS alluvial wells increase in the downstream direction. Typically maximum concentrations in 1981 were observed at far-field stations. Calcium concentrations, however, were generally higher at near-field than at either far-field or control alluvial wells. This increasing trend in the downstream direction is typical for natural systems and hence no development related effects are indicated.

c. Statistical Analysis - The results of the alluvial aquifer MANOVA for selected water quality constituents indicates that, for most major inorganic constituents, significant variability is observed for the main effects of monitoring area or station type (control, near-field, far-field) and year:

	Probability > F		
Parameter	Area	Year	Area x Year
TDS	.0001	.0026	.0006
Conducitivty	.0001	.0001	.1494
pH	.0001	.0001	.0001
Alkalinity	.0001	.4944	.2723
Calcium	.0670	.0718	.6620
Magnesium	.0001	.0227	.1539
Sodium	.0001	.0049	.5820
Fluoride	.4232	.0001	.9923
Chloride	.0075	.0518	.9097
Bicarbonate	.0001	.0442	.2286
Sulfate	.0001	.0001	.0089

The interaction term (area x year) was significant only for TDS, pH, and sulfate. Thus, for most constituents, the spatial pattern of water quality variability has not changed significantly over time.

Examination of the Hotelling-Lawley trace, Pillai's trace, and Wilk's Criterion variance analyses also indicates that area (station type) and year main effects are very significant (Appendix 5-2.7). In the case of the Roy's Maximum Root Criterion, the analysis was unable to estimate an F or a probability value for either area or year main effects. This indicates that the variability of a few constituents is greatly different from the others. For

example, only calcium and fluoride are nonsignificant (at the 0.05 level) for the area (station type) main effect. Alkalinity was very nonsignificant for the year main effect.

A Duncan's Multiple Range Test was used to examine the nature and significance of differences in means. The test results indicated that control area means were not significantly different than near-field means for sodium and chloride. Near-field and far-field means were not significantly different for TDS, alkalinity, magnesium, chloride, bicarbonate, and sulfate. Thus, control station water quality tended to be significantly different than near-field and far-field wells.

Analysis of the differences in means over years indicated the following:

Parameter	Years Significantly Different from 1981
TDS	1975, 1976, 1978, 1980
Conductivity	1975, 1979, 1980
pH	1975, 1976, 1977
Magnesium	1975, 1976, 1978, 1980
Sodium	1976, 1977, 1978
Fluoride	1975
Bicarbonate	1975, 1976, 1978, 1980
Sulfate	1975, 1976, 1978, 1980

Only those parameters with significant variability for the yearly main effect in the MANOVA were considered. The differences in means are as follows:

Parameter	1975	1976	1977	1978	1979	1980	1981
TDS	870	937	1058	835	1037	792	1047
Conductivity	1175	1311	1460	1383	2007	1088	1365
pH	6.5	6.4	6.8	7.6	7.3	7.6	7.5
Magnesium	58	65	91	58	73	59	86
Sodium	140	146	167	193	143	90	117
Fluoride	0.4	0.3	0.2	0.1	0.3	0.3	0.2
Bicarbonate	479	476	538	450	541	464	520
Sulfate	291	345	397	318	420	266	434

These results show that, beyond an increasing trend in mean pH and perhaps sulfate concentrations, and a small decline in recent years in sodium concentrations, the 1981 means are not inconsistent with earlier observations. Most of the observed changes over time, though significant statistically, do not appear to be of great magnitude nor indicative of development-induced impacts on water quality of the alluvial system.

5. Upper Aquifer

a. Field Data - Water levels in upper aquifer control wells during 1981 (Appendix 5-2.8) were similar to 1979 and 1980 observations. However, the 1981 mean water level was somewhat shallower than pre-1981 levels. Water levels for control well GS-15U are shown in Figure 5-16. The 1981 mean specific conductance for control wells was somewhat greater than 1979 and 1980 means, but the 1981 maximum level (2400 micromhos/cm) was comparable to earlier observations. The mean pH for 1981 was about the same as earlier data. However, the 1981 maximum pH (7.7) was lower than that for either 1979 or 1980.

Near-field upper aquifer wells exhibited a somewhat deeper mean water level in 1981 than in 1979 and 1980, a reflection of continued dewatering. Water levels for 1981 in near-field well CE-705AU are shown in Figure 5-17. Mean water temperatures and pH were comparable to earlier data. The 1981 mean conductivity was greater than 1979 and 1980 means; however, the minimum and maximum levels were similar.

Mean 1981 water levels at far-field upper aquifer wells were about the same as was observed in 1980. Water levels for 1981 for GS-M5U are shown in Figure 5-18. The mean specific conductance of far-field wells was greater in 1981 than in 1980, largely due to a maximum conductivity of 3300 micromhos/cm at GS-M5U. Other conductivity data were similar to earlier years. Water temperature and pH data for far-field wells during 1981 were comparable to previous observations.

b. Water Quality Analysis - Upper aquifer water quality data are presented in Appendix 5-2.9. Mean levels of most water quality parameters for upper aquifer control wells in 1981 (Table 5-18) were somewhat lower than 1980 means and somewhat greater than baseline (1976) means:

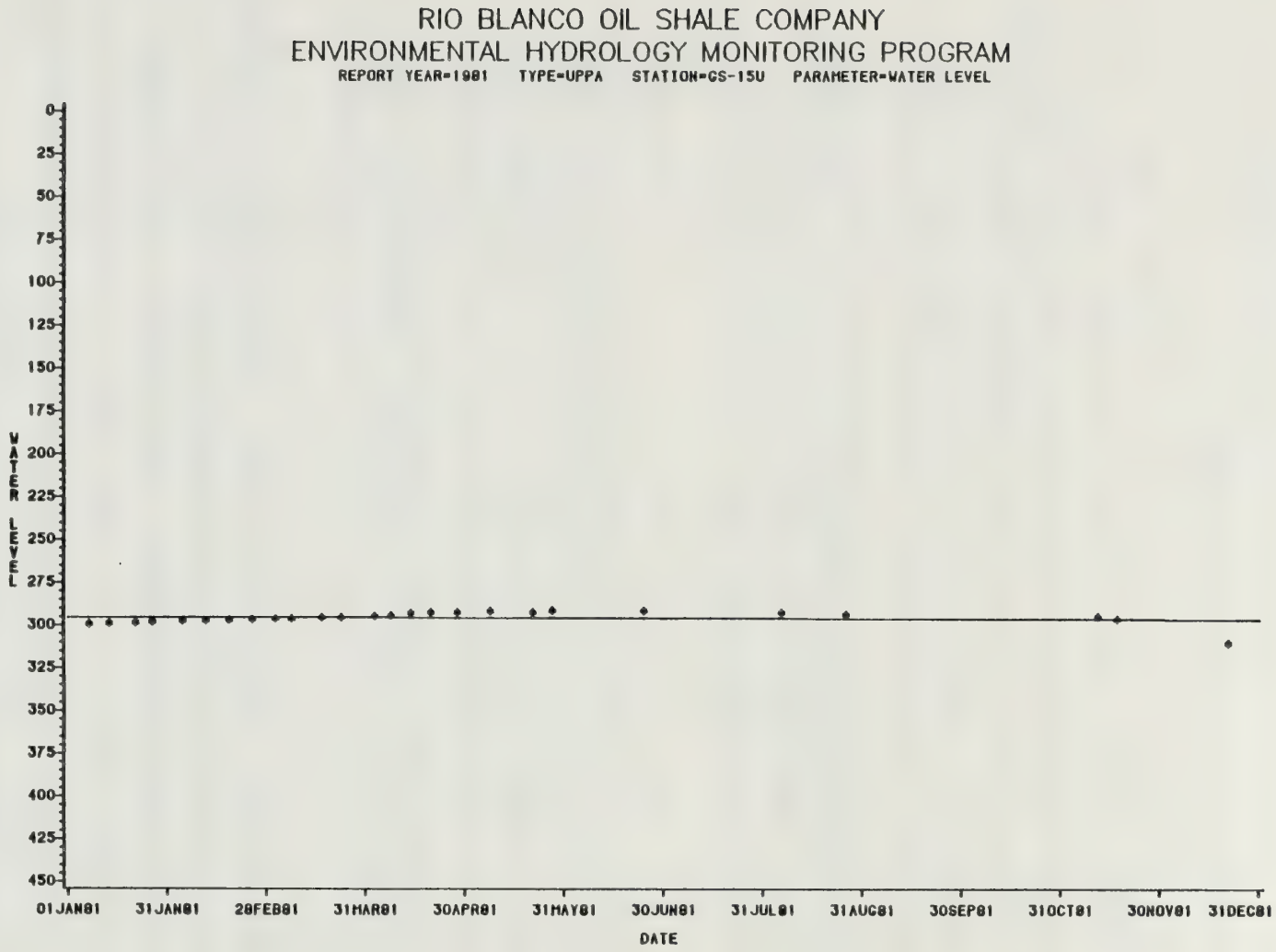


Figure 5-16. Water Level (Depth to Water, Feet) in Upper Aquifer Well GS-15U During 1981

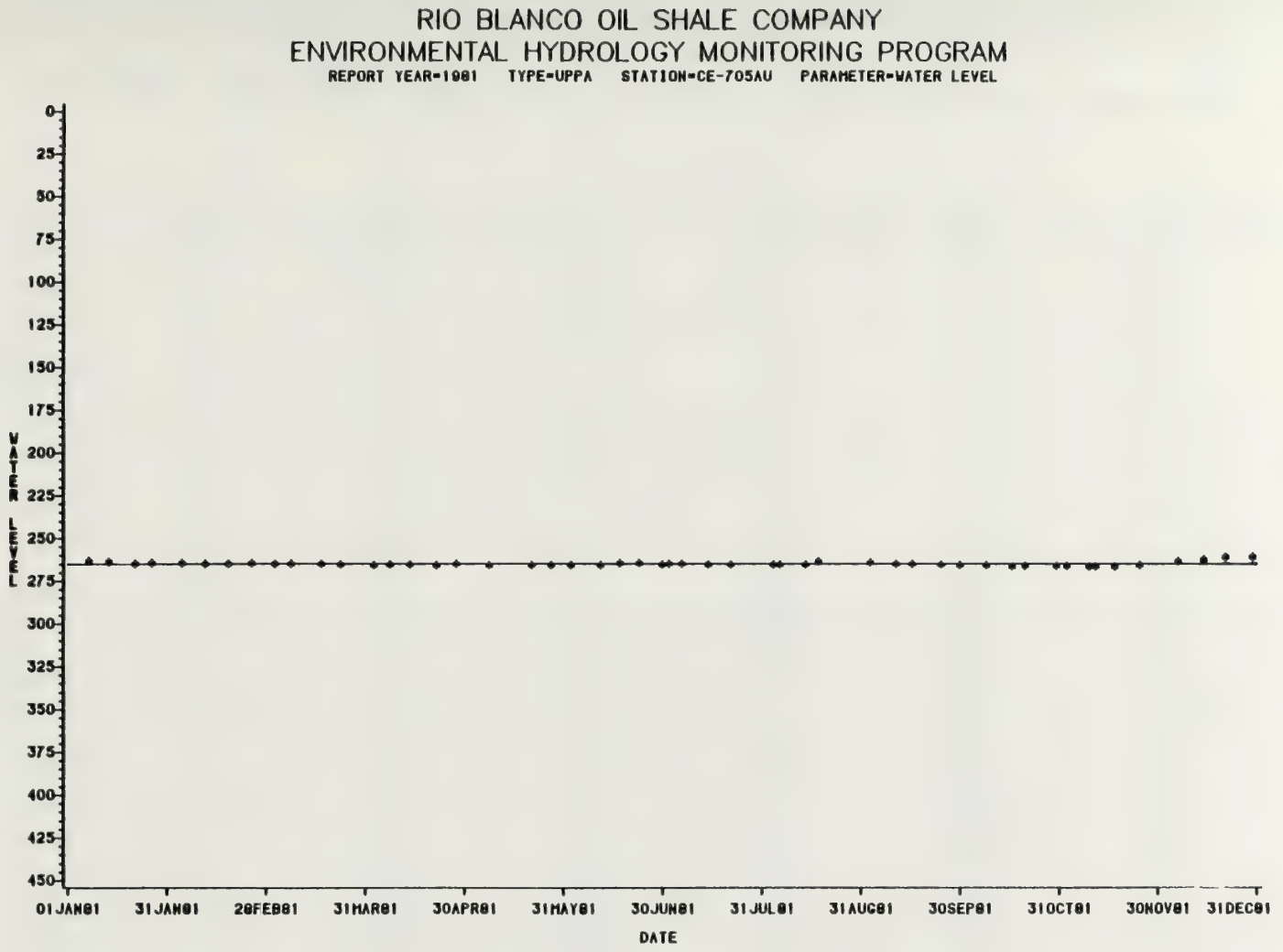


Figure 5-17. Water Level (Depth to Water, Feet) in Upper Aquifer Well CE-705AU During 1981

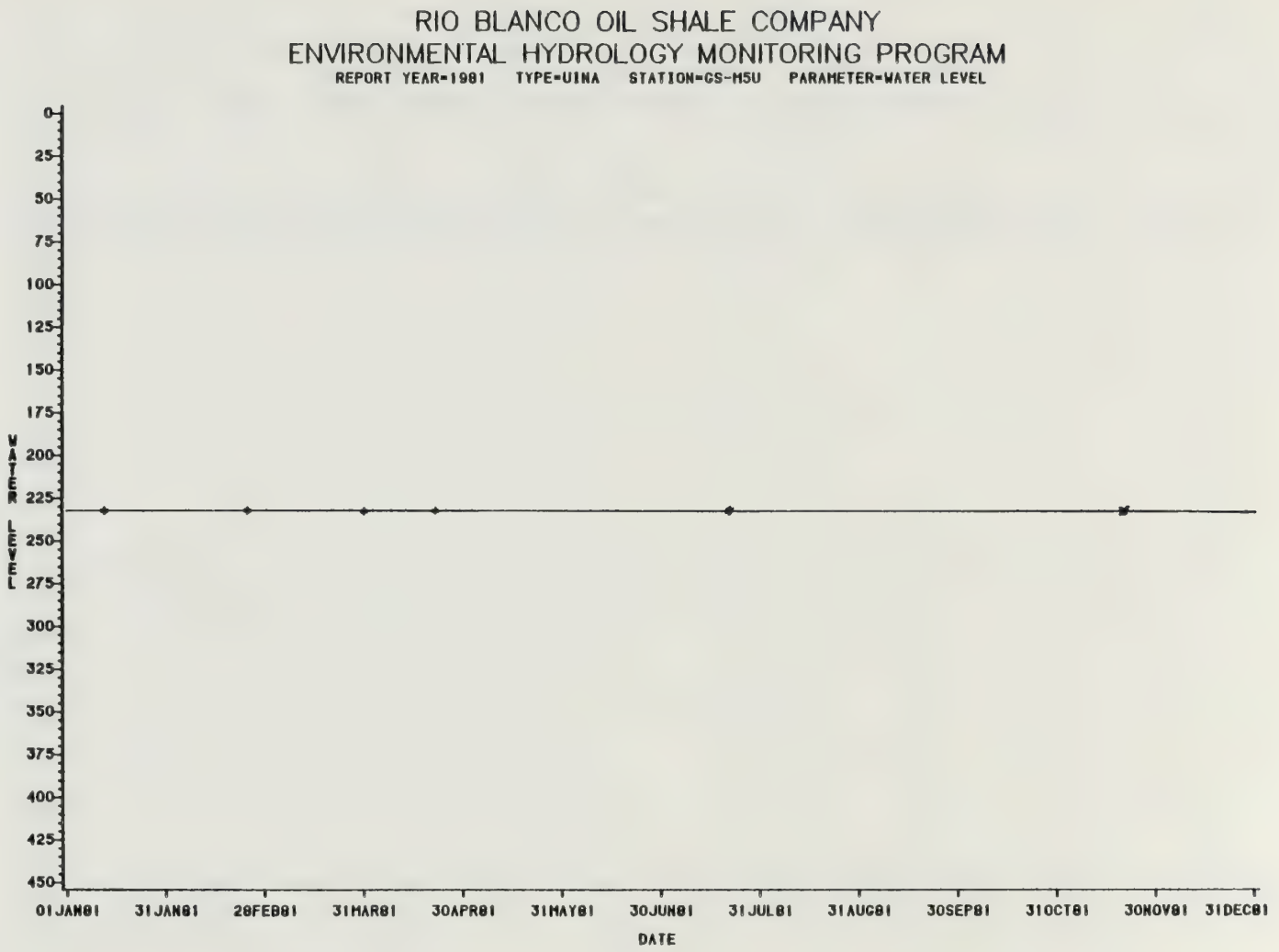


Figure 5-18. Water Level (Depth to Water, Feet) in Upper Aquifer Well GS-M5U During 1981

Table 5-18. Summary of Water Quality Data for Upper Aquifer Control Wells, MIS Monitoring Program, 1981

TYPE=UPPA AREA=CONTROL REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	15	7.51	0.46	8.80	7.00	7.00	8.80
CONDUCTIVITY	15	1743.33	466.56	2400.00	1200.00	1200.00	2400.00
TOT DIS SOLIDS	16	1385.50	462.41	2028.00	706.00	706.00	2028.00
ALKALINITY	16	515.50	103.69	662.00	374.00	374.00	662.00
CALCIUM	16	101.20	32.23	140.00	20.00	20.00	140.00
MAGNESIUM	16	101.81	38.73	170.00	58.00	58.00	170.00
POTASSIUM	16	0.66	0.19	1.04	0.34	0.34	1.04
SODIUM	16	205.81	73.96	320.00	101.00	101.00	320.00
BICARBONATE	16	597.31	130.99	775.00	427.00	427.00	775.00
CARBONATE	6	1.73	1.80	5.41	1.00	1.00	5.41
CHLORIDE	16	10.16	3.89	21.80	4.96	4.96	21.80
NITRATE	7	0.09	0.04	0.10	0.00	0.00	0.10
SULFATE	16	619.13	259.96	976.00	259.00	259.00	976.00
FLUORIDE	16	0.24	0.22	0.92	0.08	0.08	0.92
AMMONIA	15	0.82	1.17	4.60	0.07	0.07	4.60
PHOSPHATE	11	0.08	0.08	0.29	0.01	0.01	0.29
BORON	12	0.42	0.64	2.40	0.02	0.02	2.40
SILICA	16	33.19	11.97	48.00	6.00	6.00	48.00
IRON	10	3.63	3.38	11.10	0.10	0.10	11.10
DIS ORG CARBON	15	9.67	10.63	37.00	1.00	1.00	37.00
ARSENIC	2	0.01	0.00	0.01	0.01	0.01	0.01
SELENIUM	2	0.01	0.00	0.01	0.01	0.01	0.01
VANADIUM	2	0.50	0.00	0.50	0.50	0.50	0.50
MOLYBDENUM	2	0.10	0.00	0.10	0.10	0.10	0.10
MERCURY	2	0.30	0.00	0.30	0.30	0.30	0.30
ALUMINUM	2	0.10	0.00	0.10	0.10	0.10	0.10
BARIUM	2	0.10	0.00	0.10	0.10	0.10	0.10
BERYLLIUM	2	0.01	0.00	0.01	0.01	0.01	0.01
BISMUTH	2	0.01	0.00	0.01	0.01	0.01	0.01
BROMIDE	2	0.25	0.07	0.30	0.20	0.20	0.30
CADMIUM	2	0.01	0.00	0.01	0.01	0.01	0.01
CHROMIUM	2	0.01	0.00	0.01	0.01	0.01	0.01
COPPER	2	0.01	0.00	0.01	0.01	0.01	0.01
GALLIUM	2	0.50	0.00	0.50	0.50	0.50	0.50
GERMANIUM	2	0.10	0.00	0.10	0.10	0.10	0.10
LEAD	2	0.10	0.00	0.10	0.10	0.10	0.10
LITHIUM	6	0.14	0.09	0.26	0.05	0.05	0.26
MANGANESE	6	0.22	0.14	0.40	0.04	0.04	0.40
NICKEL	2	0.05	0.00	0.05	0.05	0.05	0.05
STRONTIUM	6	2.10	0.96	3.63	1.03	1.03	3.63
TITANIUM	2	0.50	0.00	0.50	0.50	0.50	0.50
ZINC	6	0.03	0.01	0.04	0.01	0.01	0.04
ZIRCONIUM	2	10.00	0.00	10.00	10.00	10.00	10.00

Parameter	1981 Mean	1980 Mean	1976 Mean
TDS	1386	1499	1264
Alkalinity	516	545	505
Calcium	101	116	77
Magnesium	102	118	71
Sodium	206	196	248
Bicarbonate	597	643	613
Sulfate	619	653	503

The general chemical composition of upper aquifer control stations has not changed appreciably since the baseline period. Maximum concentrations for 1981 were generally similar to or lower than those for 1980 or 1976; however, recent maxima for sodium and sulfate concentrations are greater than baseline maxima.

The mean concentrations of major inorganic ions in 1981 in near-field upper aquifer wells (Table 5-19) were similar to the means observed in 1980. The 1981 data exhibit generally lower concentrations for many ions than were observed during the baseline period (1976):

Parameter	1980 Mean	1981 Mean	1976 Mean
TDS	1036	997	1585
Alkalinity	457	465	1308
Calcium	60	67	14
Magnesium	77	77	40
Sodium	174	167	626
Bicarbonate	526	545	1425
Sulfate	395	358	126

A shift in composition from a sodium-bicarbonate system to mixed calcium-magnesium-bicarbonate-sulfate system is indicated by these data.

The mean concentrations of major ions in far-field upper aquifer wells in 1981 (Table 5-20) were generally similar or lower than those observed in 1980. The 1981 mean sulfate concentration (477 mg/l), however, was

Table 5-19. Summary of Water Quality Data for Upper Aquifer Near-Field Wells, MIS Monitoring Program, 1981

TYPE=UPPA AREA=NEAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	16	7.86	0.47	8.50	7.00	7.00	8.50
CONDUCTIVITY	16	1350.31	198.12	1750.00	1050.00	1050.00	1750.00
TOT DIS SOLIDS	16	1035.50	186.01	1299.00	796.00	796.00	1299.00
ALKALINITY	16	456.88	38.34	520.00	399.00	399.00	520.00
CALCIUM	16	59.88	40.05	120.00	19.00	19.00	120.00
MAGNESIUM	16	76.69	12.80	101.00	57.00	57.00	101.00
POTASSIUM	16	0.38	0.21	0.97	0.05	0.05	0.97
SODIUM	16	174.00	40.27	240.00	140.00	140.00	240.00
BICARBONATE	16	526.06	50.44	613.00	441.00	441.00	613.00
CARBONATE	8	1.22	0.26	1.78	1.00	1.00	1.78
CHLORIDE	16	11.18	2.71	16.20	7.21	7.21	16.20
NITRATE	9	0.17	0.24	0.80	0.00	0.00	0.80
SULFATE	16	394.75	97.38	559.00	212.00	212.00	559.00
FLUORIDE	16	0.53	0.65	2.48	0.09	0.09	2.48
AMMONIA	14	0.46	0.38	1.20	0.09	0.09	1.20
PHOSPHATE	11	0.06	0.09	0.31	0.01	0.01	0.31
BORON	15	0.27	0.24	1.03	0.02	0.02	1.03
SILICA	16	24.94	6.78	36.00	12.00	12.00	36.00
IRON	8	0.74	1.80	5.20	0.05	0.05	5.20
DIS ORG CARBON	16	6.69	2.96	13.00	1.00	1.00	13.00
ARSENIC	3	0.01	0.00	0.01	0.01	0.01	0.01
SELENIUM	3	0.01	0.00	0.01	0.01	0.01	0.01
VANADIUM	3	0.50	0.00	0.50	0.50	0.50	0.50
MOLYBDENUM	3	0.10	0.00	0.10	0.10	0.10	0.10
MERCURY	3	0.30	0.00	0.30	0.30	0.30	0.30
ALUMINUM	3	0.10	0.00	0.10	0.10	0.10	0.10
BARIUM	3	0.10	0.00	0.10	0.10	0.10	0.10
BERYLLIUM	3	0.01	0.00	0.01	0.01	0.01	0.01
BISMUTH	3	0.01	0.00	0.01	0.01	0.01	0.01
BROMIDE	4	0.55	0.70	1.60	0.20	0.20	1.60
CADMIUM	3	0.01	0.00	0.01	0.01	0.01	0.01
CHROMIUM	3	0.01	0.00	0.01	0.01	0.01	0.01
COPPER	3	0.01	0.00	0.01	0.01	0.01	0.01
GALLIUM	3	0.50	0.00	0.50	0.50	0.50	0.50
GERMANIUM	3	0.10	0.00	0.10	0.10	0.10	0.10
LEAD	3	0.10	0.00	0.10	0.10	0.10	0.10
LITHIUM	7	0.11	0.04	0.20	0.08	0.08	0.20
MANGANESE	7	0.06	0.05	0.15	0.01	0.01	0.15
NICKEL	4	0.05	0.00	0.05	0.05	0.05	0.05
STRONTIUM	7	3.64	1.17	5.40	2.35	2.35	5.40
TITANIUM	3	0.50	0.00	0.50	0.50	0.50	0.50
ZINC	7	0.02	0.01	0.04	0.01	0.01	0.04
ZIRCONIUM	3	10.00	0.00	10.00	10.00	10.00	10.00

Table 5-20. Summary of Water Quality Data for Upper Aquifer Far-Field Wells, MIS Monitoring Program, 1981

TYPE=UPPA AREA=FAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	10	9.53	0.17	9.80	9.20	9.20	9.80
CONDUCTIVITY	10	1391.00	96.75	1575.00	1275.00	1275.00	1575.00
TOT DIS SOLIDS	10	1005.30	118.43	1180.00	780.00	780.00	1180.00
ALKALINITY	10	522.20	73.97	679.00	434.00	434.00	679.00
CALCIUM	10	4.72	0.78	5.80	3.70	3.70	5.80
MAGNESIUM	10	76.60	29.58	120.00	48.00	48.00	120.00
POTASSIUM	10	3.05	1.96	6.80	1.26	1.26	6.80
SODIUM	10	234.10	30.13	270.00	198.00	198.00	270.00
BICARBONATE	10	336.30	73.71	464.00	254.00	254.00	464.00
CARBONATE	10	13.81	2.71	17.40	9.61	9.61	17.40
CHLORIDE	10	15.95	5.62	25.20	7.21	7.21	25.20
NITRATE	2	0.10	0.00	0.10	0.10	0.10	0.10
SULFATE	10	476.90	99.96	660.00	312.00	312.00	660.00
FLUORIDE	10	0.44	0.48	1.56	0.03	0.03	1.56
AMMONIA	7	1.12	0.97	2.78	0.20	0.20	2.78
PHOSPHATE	9	0.08	0.03	0.13	0.01	0.01	0.13
BORON	8	0.23	0.21	0.68	0.01	0.01	0.68
SILICA	8	1.75	0.85	3.00	0.50	0.50	3.00
IRON	2	0.05	0.00	0.05	0.05	0.05	0.05
DIS ORG CARBON	10	6.70	3.74	12.00	1.00	1.00	12.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	0	.	.	.	.	.	.
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	2	0.12	0.06	0.16	0.08	0.08	0.16
MANGANESE	1	0.04	.	0.04	0.04	0.04	0.04
NICKEL	0	.	.	.	.	.	.
STRONTIUM	2	0.91	1.20	1.76	0.07	0.07	1.76
TITANIUM	0	.	.	.	.	.	.
ZINC	0	.	.	.	.	.	.
ZIRCONIUM	0	.	.	.	.	.	.

appreciably greater than the 1980 mean (385 mg/l). The 1981 mean concentrations indicate decreased salinity relative to 1976, due largely to decreases in calcium, bicarbonate, and sulfate levels.

In the upper aquifer wells monitored in 1981 for the MIS Area hydrology monitoring program, the mean salinity generally decreased in the downgradient direction (from control to near-field to far-field). This trend was mostly attributable to decreases in calcium, bicarbonate, and sulfate concentrations:

Parameter	Control	Near-Field	Far-Field
TDS	1386	1036	1005
Calcium	101	60	4.7
Bicarbonate	597	526	336
Sulfate	619	395	477

No impact-related trends, such as increased concentrations in the near-field wells are apparent from these observations.

c. Statistical Analysis - The results of the MANOVA for selected water quality constituents indicates that, for most major inorganic constituents, significant variability is observed for the main effects, area (station type) and year. Significant variability over the MIS upper monitoring areas was observed for all tested constituents except conductivity and sodium:

	Probability > F		
Parameter	Area	Year	Area x Year
TDS	.0034	.3510	.0084
Conductivity	.1115	.0863	.0010
pH	.0001	.0001	.0001
Alkalinity	.0355	.0117	.0001
Calcium	.0001	.0860	.0249
Magnesium	.0001	.0007	.0036
Sodium	.1944	.0001	.0004
Fluoride	.0002	.0008	.0003
Chloride	.0068	.0217	.0017
Bicarbonate	.0005	.0006	.0005
Sulfate	.0001	.0131	.0680

Significant temporal variability (year main effect) was noted for all constituents except TDS, conductivity, and calcium. Only sulfate exhibited a nonsignificant interaction term (area x year). Tests on the overall area (station type) effect and overall year main effect were highly significant (Pr>F=0.0001 for all three tests, Appendix 5-2.10). For the Roy's Maximum Root Criterion, the analysis was unable to estimate F or a probability value for either the area or year effect. This is probably a reflection of the few constituents for which the area (station type) and year main effects were nonsignificant (e.g., conductivity and sodium for the area main effect and TDS, conductivity, and calcium for the year effect).

Duncan's Multiple Range Test was used to examine differences in means for constituents for which significant main effect terms were observed from the MANOVA. All three monitoring areas (station types -- control, near-field, far-field) were significantly different for pH, calcium, bicarbonate, and sulfate. Control and far-field station groups were not significantly different for alkalinity, magnesium, and fluoride. Control and near-field wells were significantly different for all constituents. Means for these station groups are as follows:

	Mean		
Parameter	Control	Near-Field	Far-Field
TDS	1397	1184	1125
pH	7.2	7.5	8.3
Alkalinity	538	670	517
Calcium	107	57	27
Magnesium	94	67	94
Fluoride	0.6	3.7	0.7
Chloride	11	17	16
Bicarbonate	633	771	462
Sulfate	578	315	487

These data indicate that the mean concentrations for control stations are generally greater than or comparable to those for near-field and

far-field wells. Exceptions to this generalization are pH and chloride concentrations which generally increase in the down-gradient direction.

The years for which means were significantly different from 1981 are as follows:

Parameter	Years Significantly Different from 1981
pH	1975, 1976
Alkalinity	1975, 1976
Magnesium	none
Sodium	1975, 1976
Fluoride	1975, 1976
Chloride	1976
Bicarbonate	1975, 1976
Sulfate	none

Differences in means over monitoring years are summarized as follows:

	Means					
Parameter	1975	1976	1978	1979	1980	1981
pH	6.7	6.8	7.6	8.0	8.0	8.1
Alkalinity	663	824	373	492	546	491
Sodium	323	408	213	217	194	199
Fluoride	3.6	4.6	.9	.7	.7	.4
Chloride	17	22	7	12	12	12
Bicarbonate	777	942	440	575	582	502

These results indicate an increasing trend in pH over time in the upper aquifer, and general decreases in alkalinity, sodium, fluoride, and chloride concentrations since the baseline. Observations of mean concentrations in recent years have been fairly stable and development-related impacts are not evident.

6. Lower Aquifer

Lower aquifer well GS-15L is included as a control station in the MIS Area hydrology monitoring program. The 1981 mean water levels (Figure 5-19), pH, and water temperature data were similar to observations for previous years. The field-measured conductivity (3750 micromhos/cm) was greater than that observed in earlier years but represented only a single observation. The 1981 mean TDS and alkalinity concentrations (Table 5-21) were appreciably greater than those observed in 1980. This was caused principally by increases in sodium and bicarbonate ion concentrations:

Parameter	1981 Mean	1980 Mean	1976 Mean
TDS	2454	2297	1745
Alkalinity	1964	1582	978
Sodium	998	809	575
Bicarbonate	2257	1757	1153

These data reflect an increasing trend in concentrations of these constituents since the baseline period. The trend is probably related to upper-lower aquifer interconnections during the baseline period. The more recent data are more characteristic of lower aquifer water quality.

7. Erosion and Sedimentation

Cross-sectional profiles at erosion and sedimentation stations are plotted in Figures 5-20 thru 5-29. These monitoring stations are located along the Corral Gulch drainage. Stations YES-1A, -3, and -4 are above the confluence of Corral Gulch and Dry Fork. The stream cross-section profile at YES-1A (Figure 5-20) experienced some downcutting in the channel bottom (~ 1.5 feet) during the January-June 1980 period. The channel has been fairly stable since mid-1980.

Station YES-3 (Figure 5-21) exhibited some deposition (~ .75 feet) in the channel bottom in the spring of 1980, although the general contours remained

Table 5-21. Summary of Water Quality Data for Lower Aquifer Well GS-15L, 1981

TYPE=LOWER AQUIFER STATION = GS-15L REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	5	8.34	0.44	9.00	7.90	7.90	9.00
CONDUCTIVITY	5	3702.00	510.66	4250.00	2900.00	2900.00	4250.00
TOT DIS SOLIDS	5	2454.20	321.81	2832.00	2100.00	2100.00	2832.00
ALKALINITY	5	1963.80	237.45	2264.00	1728.00	1728.00	2264.00
CALCIUM	5	2.91	0.26	3.20	2.50	2.50	3.20
MAGNESIUM	5	30.00	5.48	36.00	26.00	26.00	36.00
POTASSIUM	5	2.07	0.19	2.30	1.77	1.77	2.30
SODIUM	5	998.00	141.49	1180.00	860.00	860.00	1180.00
BICARBONATE	5	2256.60	314.09	2651.00	1901.00	1901.00	2651.00
CARBONATE	4	2.59	1.46	4.57	1.03	1.03	4.57
CHLORIDE	5	67.28	9.10	76.00	53.80	53.80	76.00
NITRATE	2	0.10	0.00	0.10	0.10	0.10	0.10
SULFATE	5	249.00	66.60	293.00	132.00	132.00	293.00
FLUORIDE	5	24.08	23.01	62.90	4.10	4.10	62.90
AMMONIA	4	0.75	1.22	2.58	0.10	0.10	2.58
PHOSPHATE	4	0.05	0.04	0.11	0.01	0.01	0.11
BORON	4	1.37	1.37	3.30	0.21	0.21	3.30
SILICA	5	8.00	1.87	10.00	5.00	5.00	10.00
IRON	1	0.05	.	0.05	0.05	0.05	0.05
DIS ORG CARBON	5	9.20	7.98	22.00	3.00	3.00	22.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	0	.	.	.	.	.	.
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	1	0.39	.	0.39	0.39	0.39	0.39
MANGANESE	1	0.01	.	0.01	0.01	0.01	0.01
NICKEL	0	.	.	.	.	.	.
STRONTIUM	1	0.09	.	0.09	0.09	0.09	0.09
TITANIUM	0	.	.	.	.	.	.
ZINC	1	0.03	.	0.03	0.03	0.03	0.03
ZIRCONIUM	0	.	.	.	.	.	.

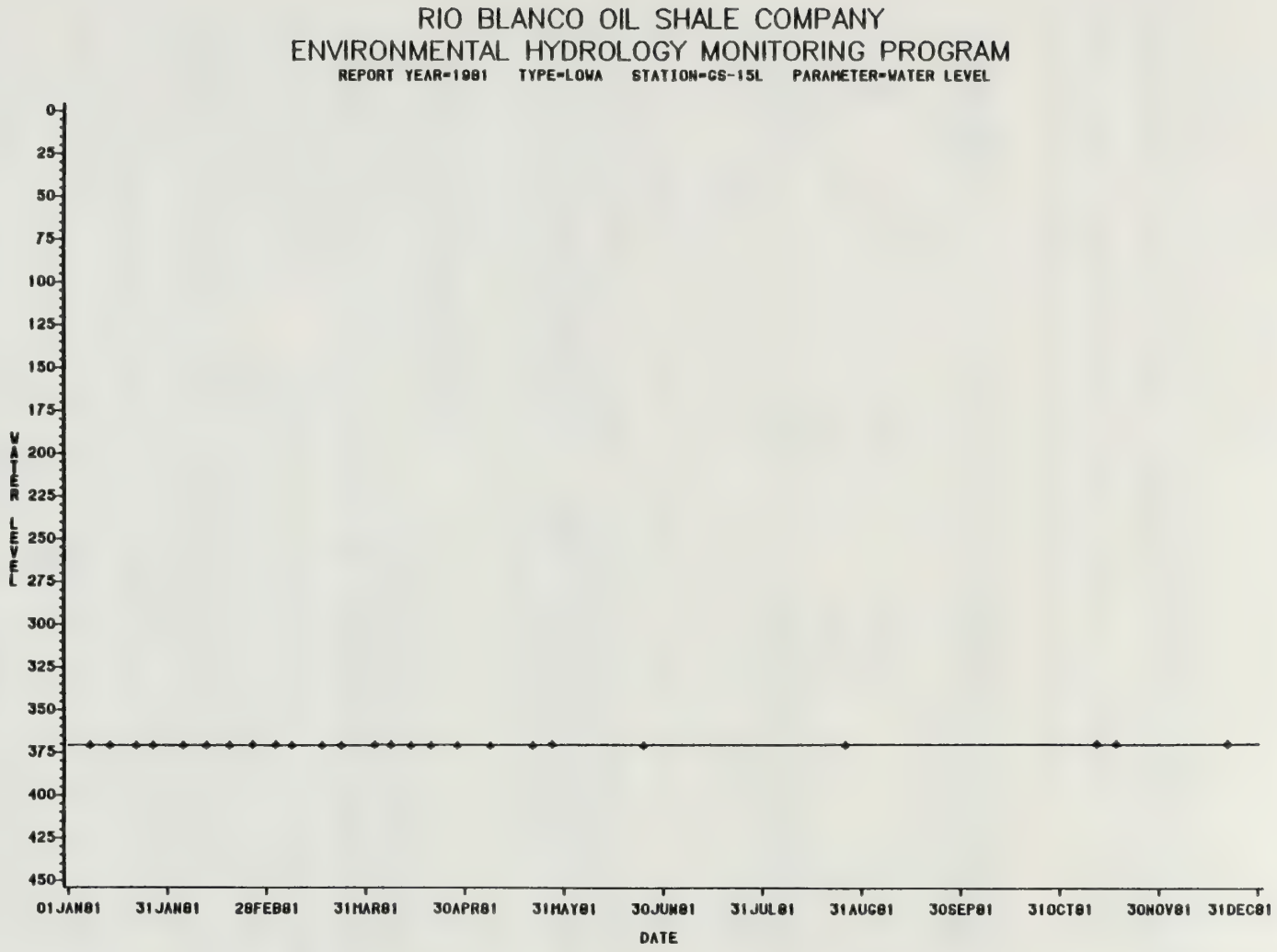


Figure 5-19. Water Level (Depth to Water, Feet) in Lower Aquifer Well GS-15L During 1981

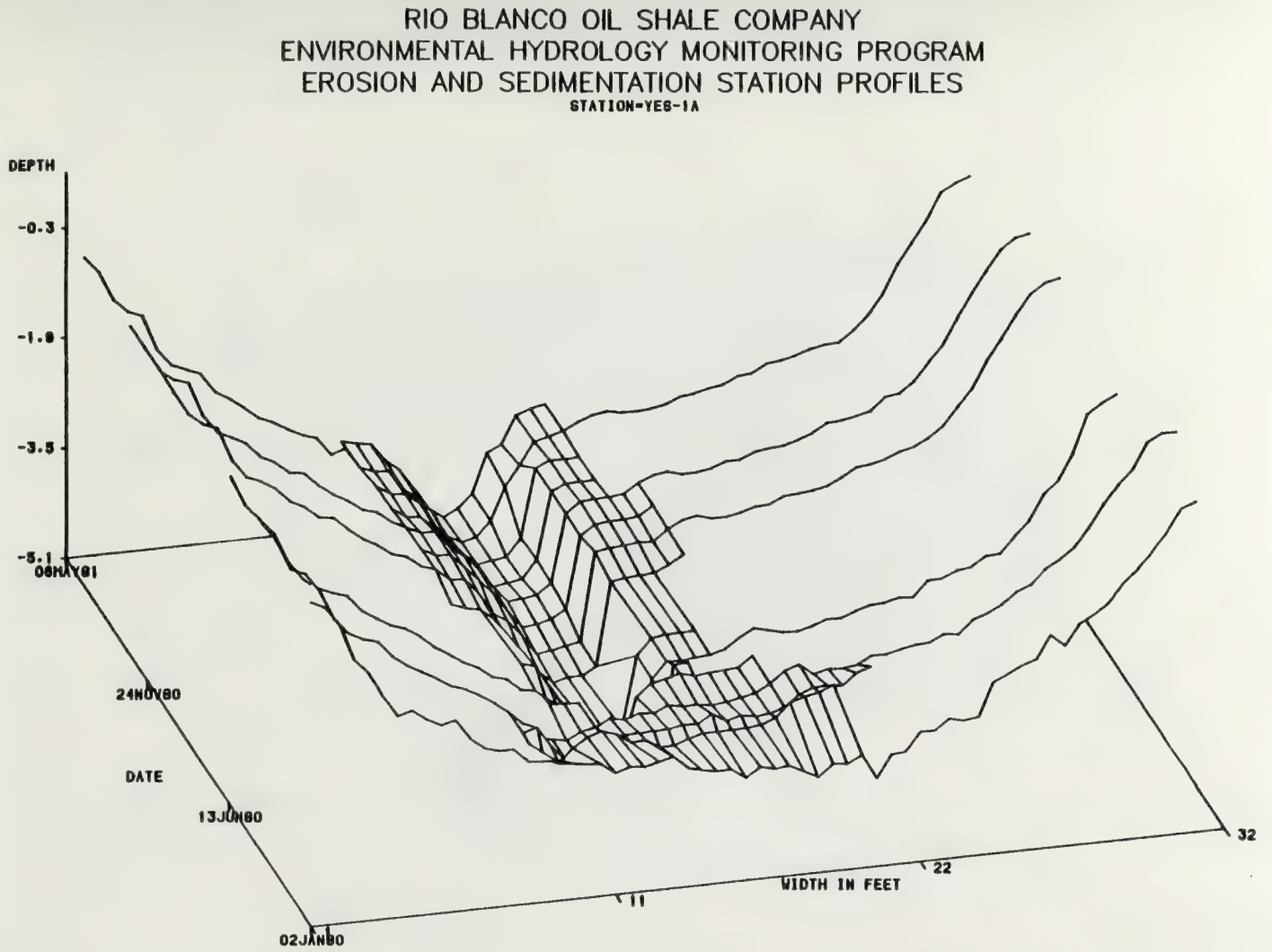


Figure 5-20. Erosion and Sedimentation Profile for Station YES-1A

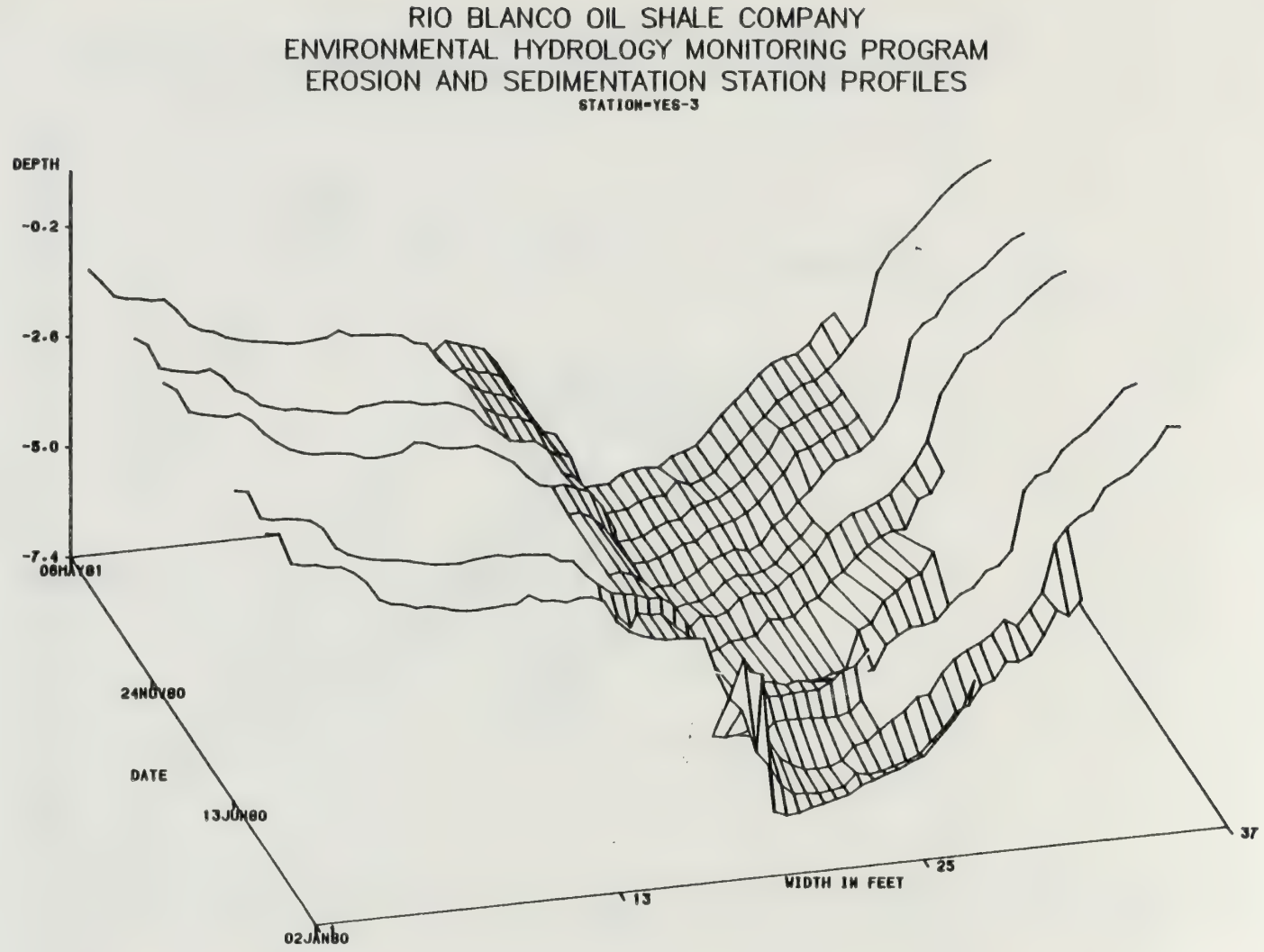


Figure 5-21. Erosion and Sedimentation Profile for Station YES-3

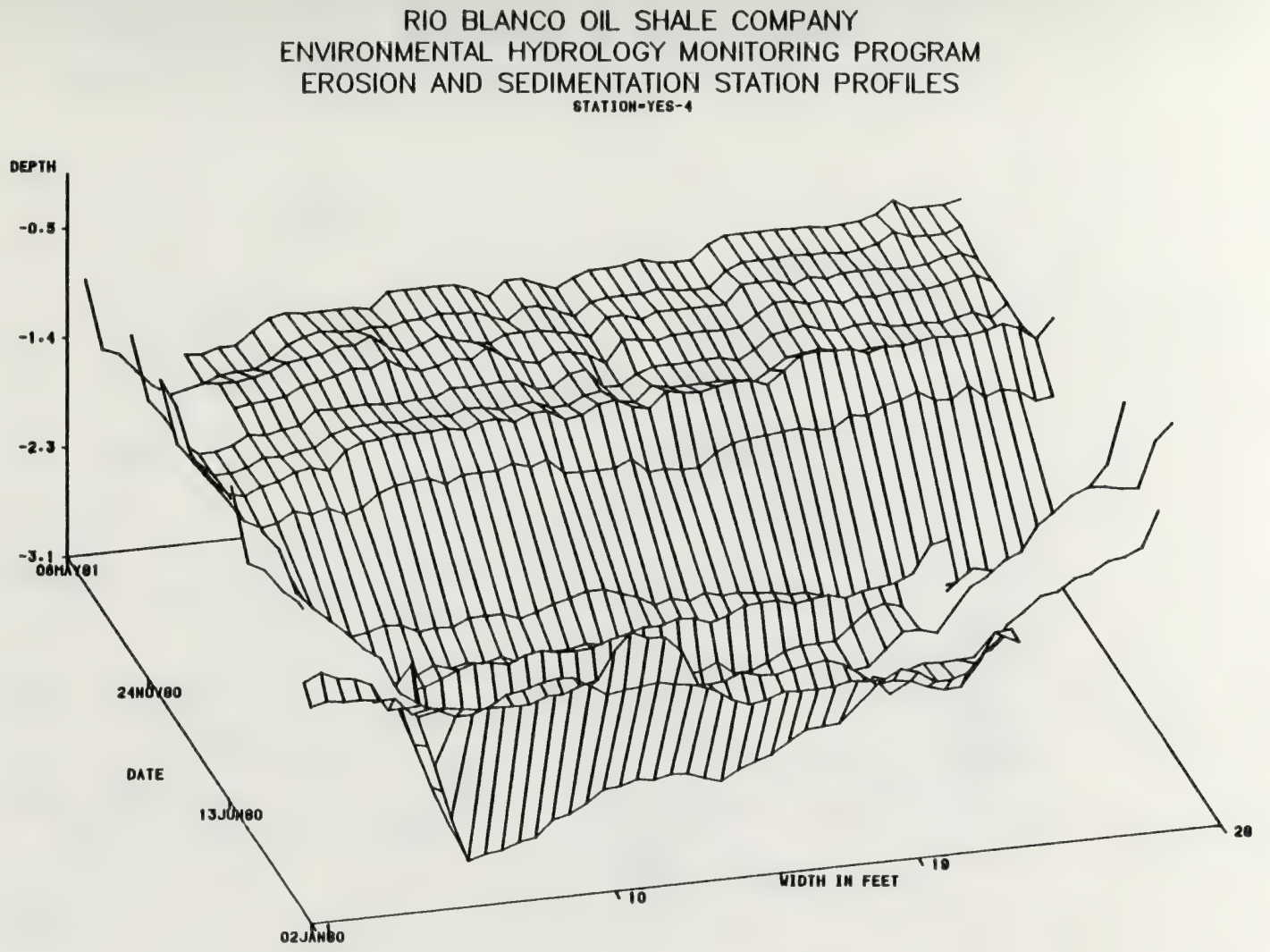


Figure 5-22. Erosion and Sedimentation Profile for Station YES-4

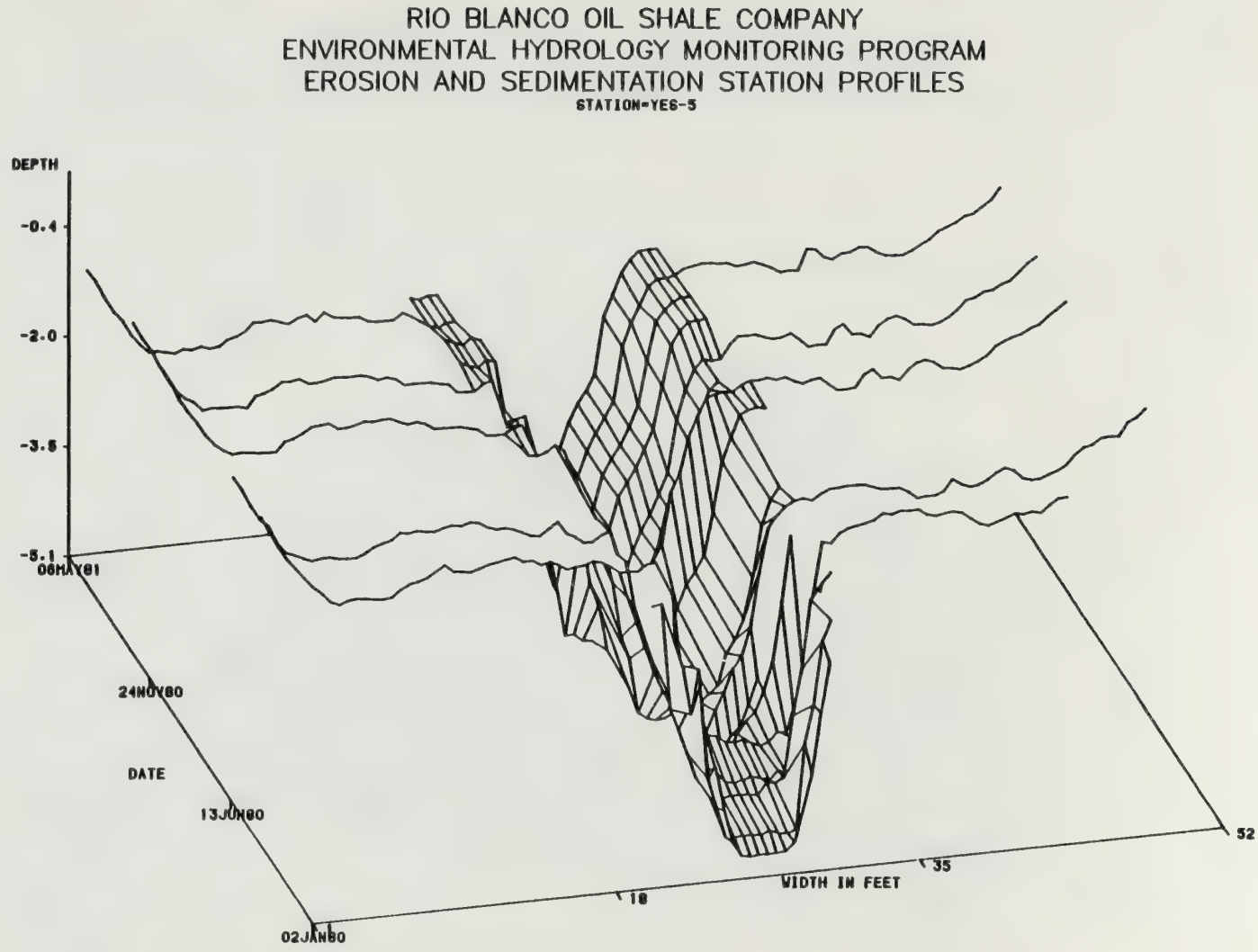


Figure 5-23. Erosion and Sedimentation Profile for Station YES-5

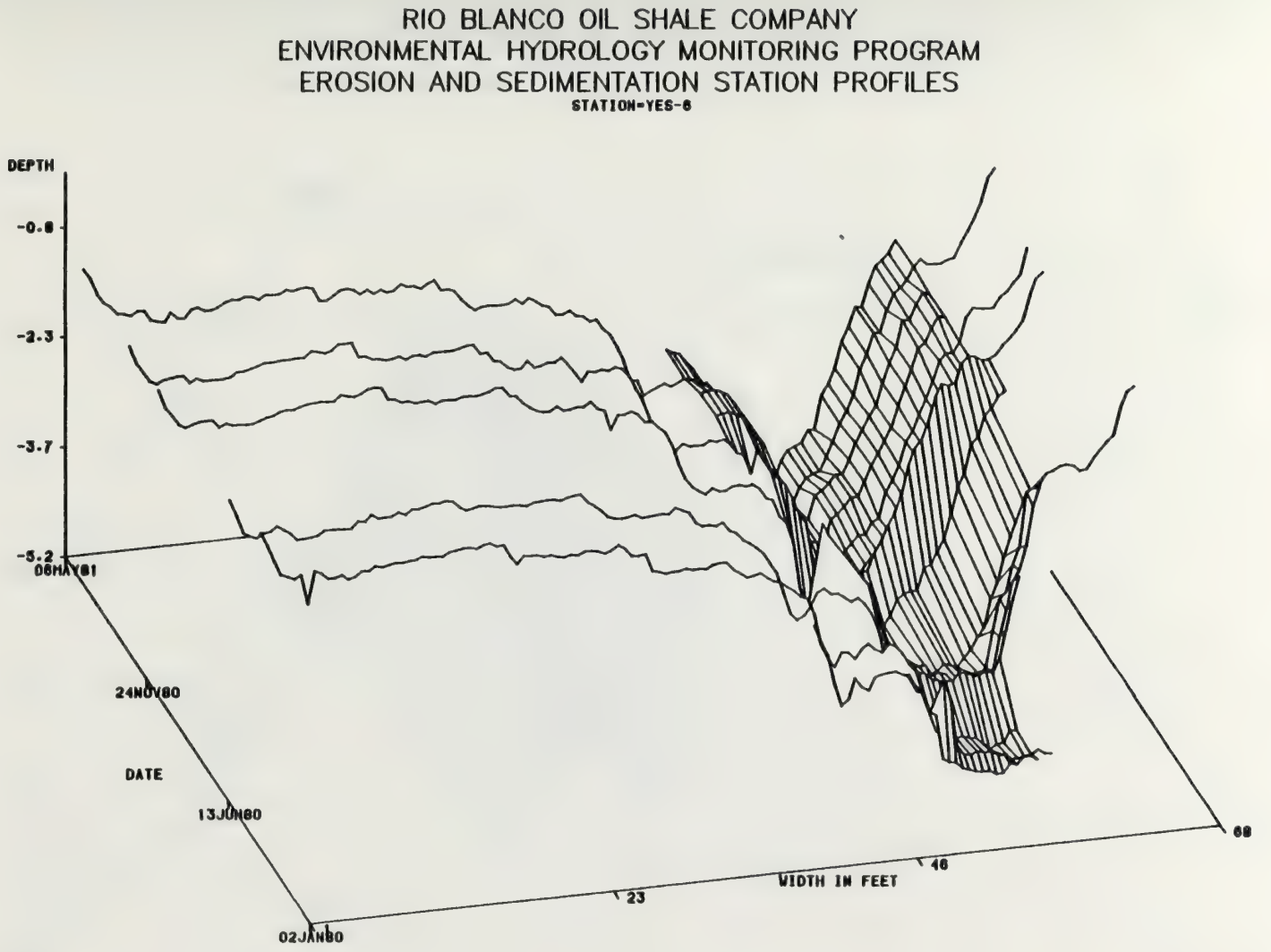


Figure 5-24. Erosion and Sedimentation Profile for Station YES-6

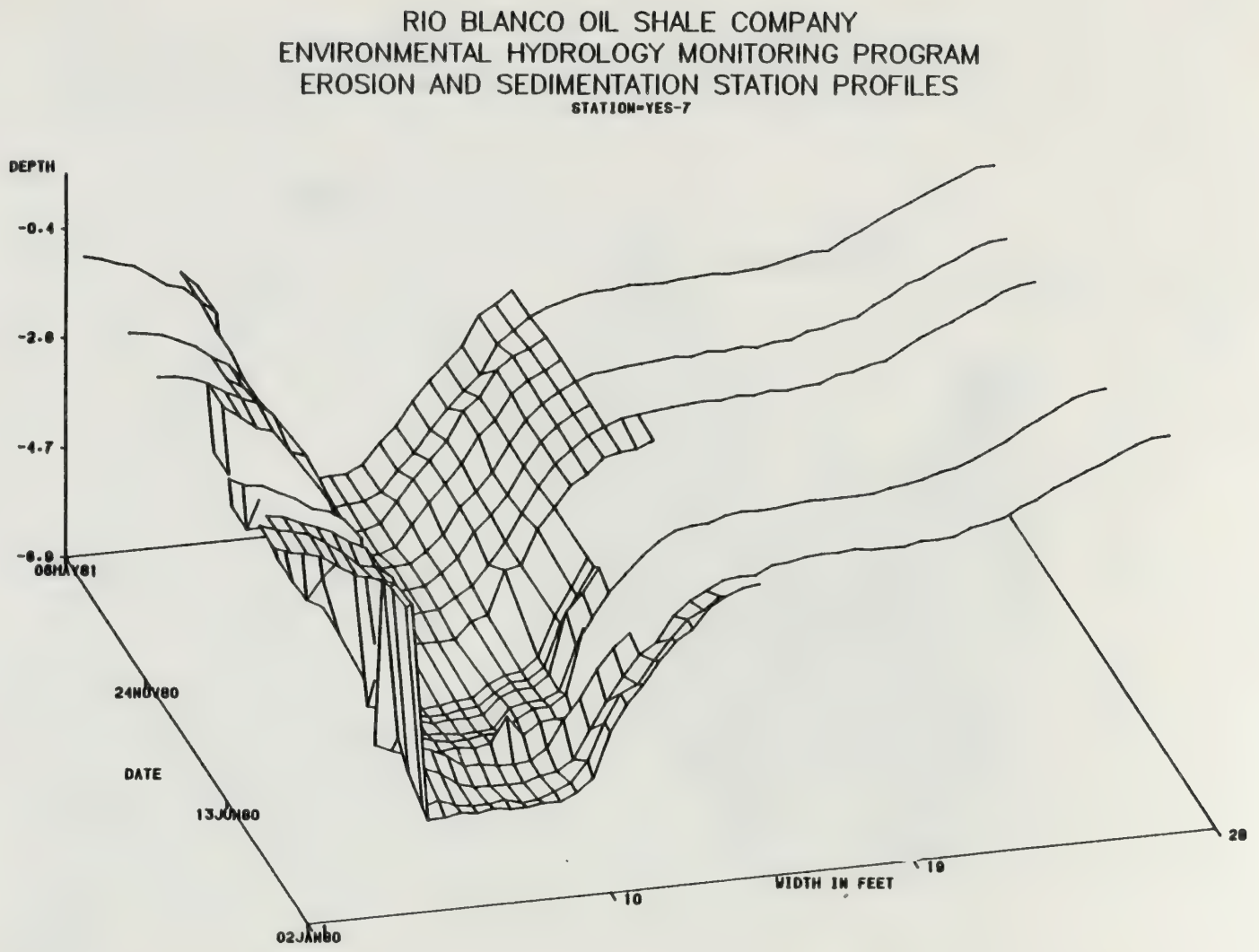


Figure 5-25. Erosion and Sedimentation Profile for Station YES-7

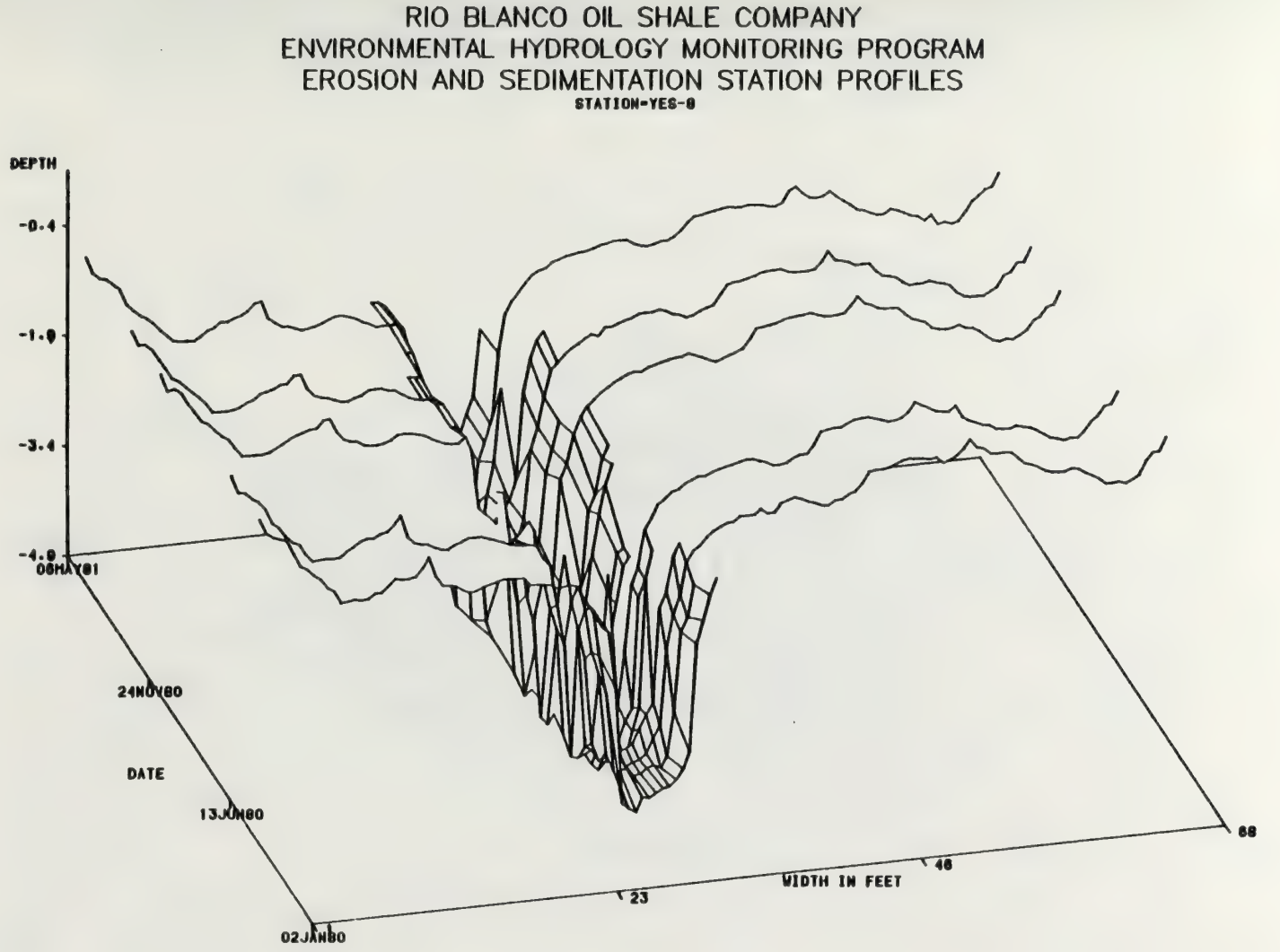


Figure 5-26. Erosion and Sedimentation Profile for Station YES-8

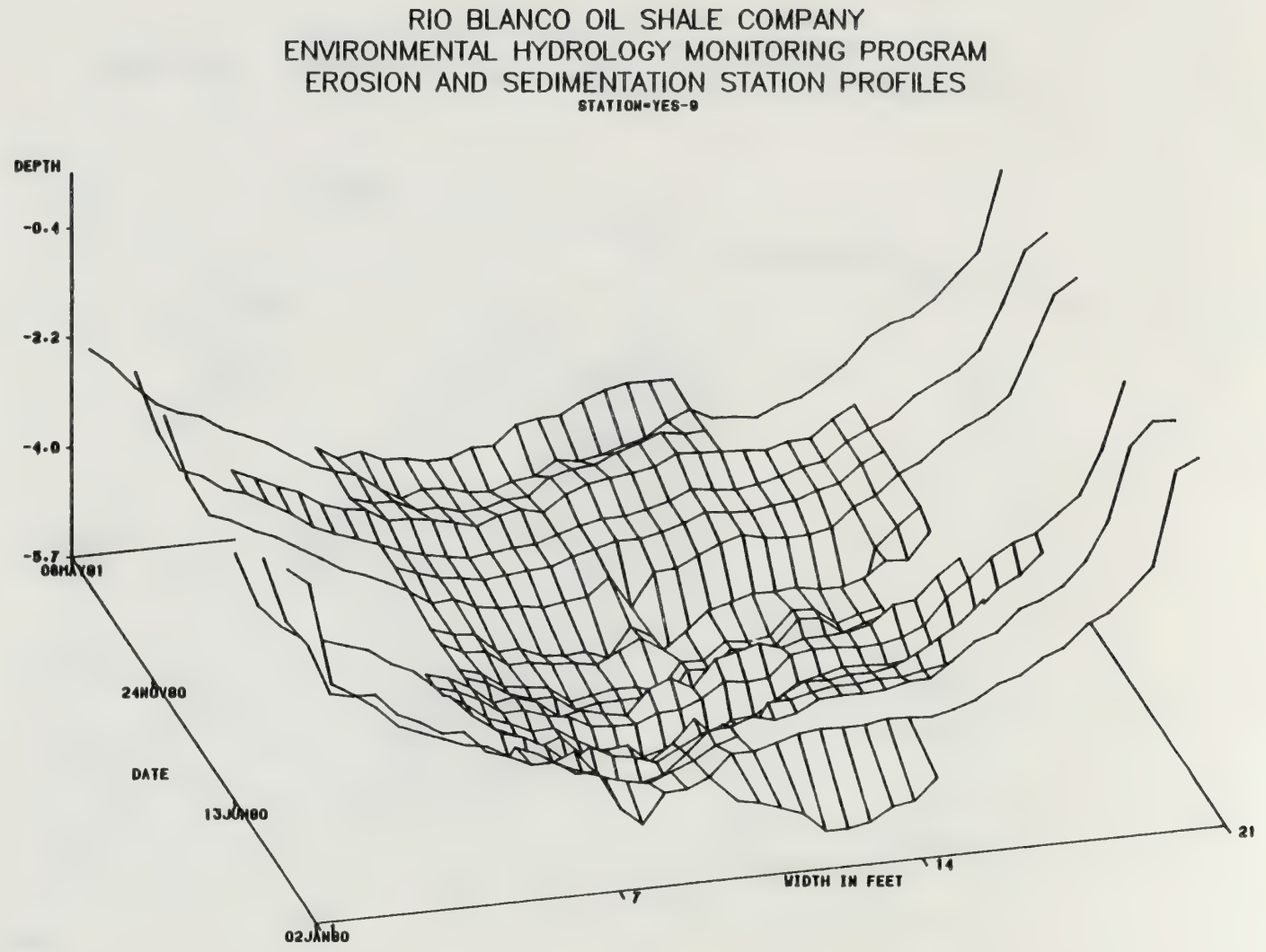


Figure 5-27. Erosion and Sedimentation Profile for Station YES-9

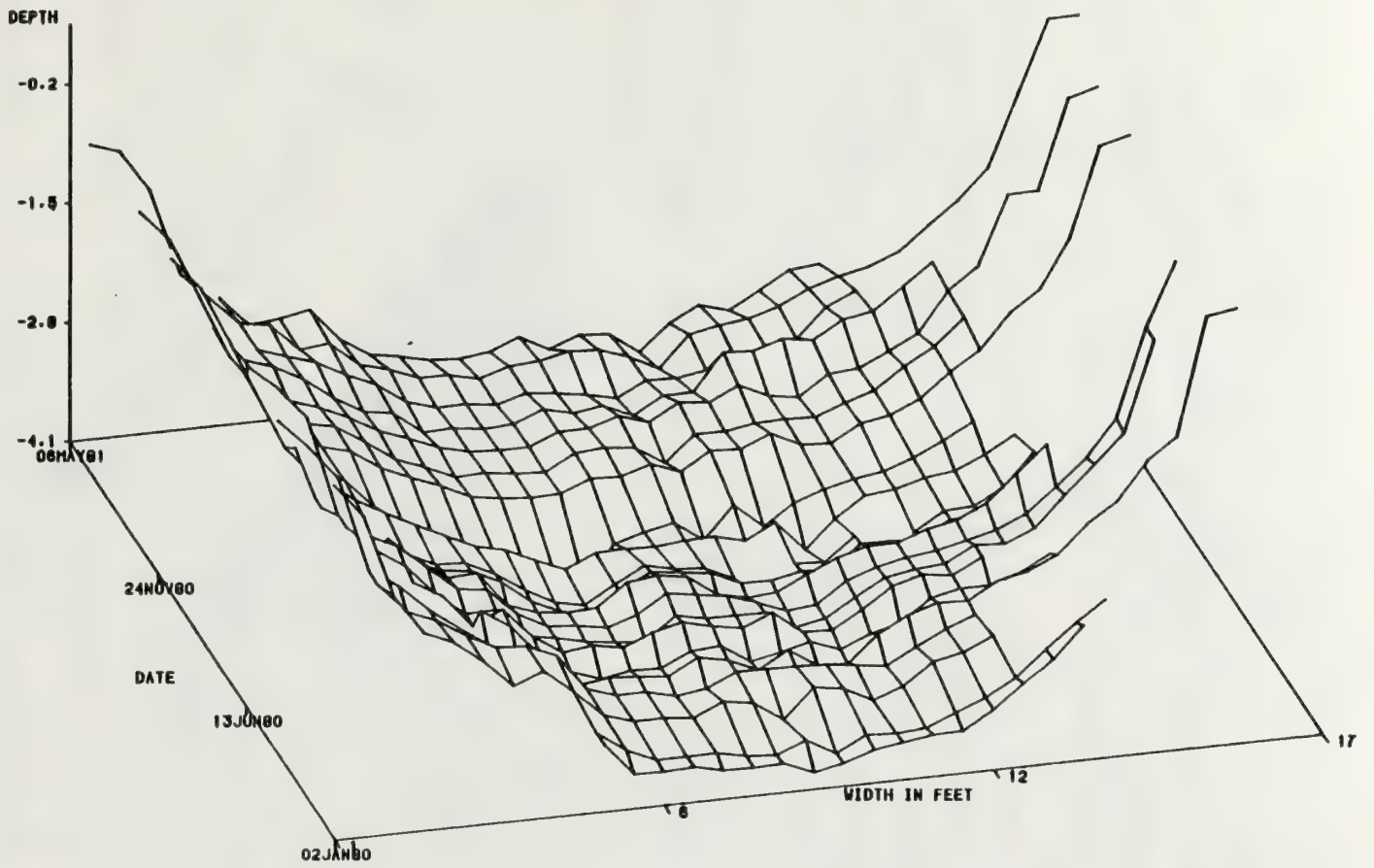


Figure 5-28. Erosion and Sedimentation Profile for Station YES-10

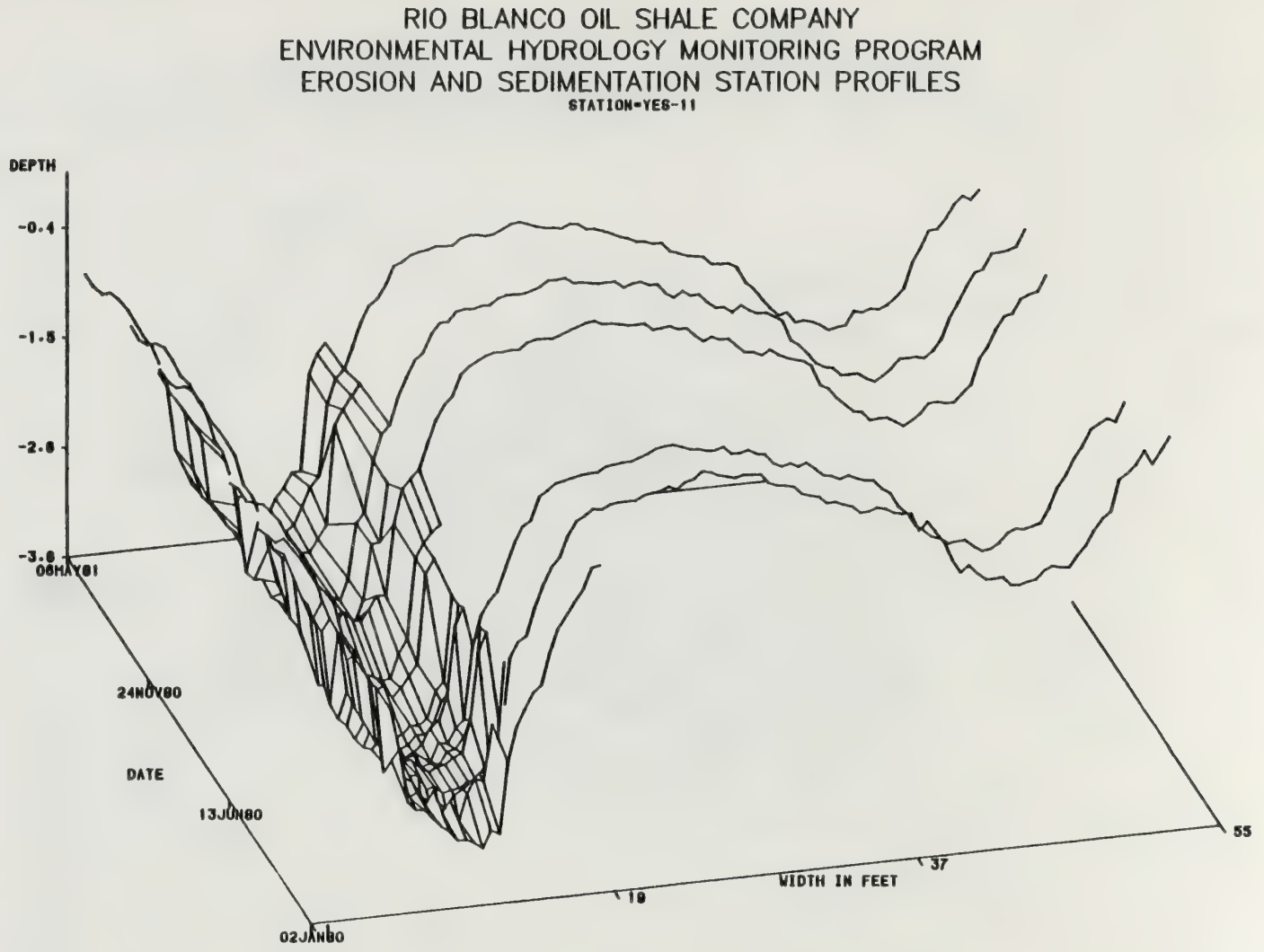


Figure 5-29. Erosion and Sedimentation Profile for Station YES-11

stable. The channel bottom was eroded approximately 1.5 feet in the June-October 1980 period. The contours and channel depth have been fairly stable since that time for the period of record.

The Corral Gulch channel at YES-4 (Figure 5-22) experienced broad downcutting in the January-April 1980 period with erosion of 1 to 1.5 feet across about 10 feet of channel bottom cross-section. This cutting was followed by about 0.75 feet of deposition across much of the channel bottom by June 1980 and deposition of another 0.75 feet by the fall of 1980. The channel cross section was relatively stable thereafter for the period of record.

Profile stations YES-5, -6, and -7 are located adjacent to and closely downstream of the MIS process area. During the spring-summer 1980 period, YES-5 (Figure 5-23) exhibited slight (~ 0.5 feet) erosion of the channel bottom. The channel was somewhat wider by October 1980 but the depth was unchanged. The channel was fairly stable thereafter for the period of record.

The stream channel at YES-6 (Figure 5-24) was fairly stable the during summer and fall of 1980. Similar cross section observations were made at this station during 1981.

No significant changes in cross-section profile at YES-7 (Figure 5-25) were observed during the spring and summer of 1980. Some deposition (~ 0.5 feet) was noted during the summer and fall of 1980. The channel has been fairly stable since that time for the period of record.

Stations YES-8 through -11 are located to the east of Tract C-a in the Corral Gulch drainage. Station YES-8 (Figure 5-26) exhibited some slight downcutting during the spring to summer 1980 period. The channel bottom was cut another ~ 0.5 foot by the fall of 1980. Deposition of about 0.75 feet was noted between the end of 1980 and March of 1981.

The stream channel at YES-9 (Figure 5-27) experienced some deposition (~ 0.5 feet) in part of the channel bottom in the first half of 1980 but little change in the channel maximum depth was observed. The channel profile was fairly stable through the fall of 1980 with only very local cutting and

deposition and no change in the overall character of the channel cross section. Deposition of about 0.5 feet across about 10 feet of the channel bottom was noted in the last quarter of 1980. The channel configuration was stable thru the mid-1981 period of record presented here.

The cross section at YES-10 (Figure 5-28) was fairly stable throughout the monitoring period with only minor deposition (~ 0.5 feet) in part of the channel. Station YES-11 (Figure 5-29) exhibited some erosional cutting during the spring of 1980. This was followed by a similar extent of deposition and general flattening of the channel bottom by the fall of 1980.

Several erosion and sedimentation monitoring stations were destroyed in the fall of 1981. These stations are being reconstructed and resurveyed to continue this monitoring effort.

5.3 LURGI PLANT SITE

A. Objectives and Methods

The monitoring program for the Lurgi plant site was designed to monitor the hydrologic effects of the proposed Lurgi demonstration project facilities. Construction of this facility, to be located north of Tract C-a, has been delayed. Hence, hydrological data collection and analysis is currently oriented to the definition of baseline or pre-development conditions in the plant site area streams, springs, alluvial aquifers, and deep aquifers. Sampling methods are described in previous reports.

Stations included in the Lurgi plant site monitoring program are as follows (RBOSC, 1981):

Station Class	Station and Identification	
Type I Control	Springs & Seeps	
	SPG-3	SPG-8
	SPG-4	SPG-20
	Alluvial Aquifer	
	GS-S24	
	Deep Aquifer	
	GS-M1U	GS-M7U
Type II Near-Field	Streams	
	H-USGS (new, construction delayed until project definition)	
	YUPRYEL	
	Impoundments (to be monitored when constructed)	
	Runoff ponds	
	Wastewater ponds	
	Alluvial Aquifer	
	GS-S15	GS-S17
	GS-S16	GS-S18
	GS-S22	GS-S23
	Deep Aquifer	
	GS-M6U	GS-M8U

Type III Far-Field	Streams	
	F-USGS	
	Alluvial Aquifer	
	GS-S28	GS-S29A
	GS-S28A	GS-S30
	GS-S29	GS-S30A
	Deep Aquifer	
	GS-M2U	GS-M5U
	GS-M3U	

B. Results and Discussion

Descriptions of the spatial and temporal variability of the Lurgi plant site hydrology data have been developed. Comparisons of the 1981 monitoring data with 1980 observations are provided. In addition, comparison of control, near-field and far-field station groups have been made for alluvial and deep aquifer wells. Analysis of variance procedures have been used to evaluate the significance of observed variations. These evaluations will provide a basis for analysis of the effects of future Lurgi plant site development activities.

1. Springs and Seeps

Four spring and seep monitoring stations function as control stations for the Lurgi plant site. Mean concentrations of water quality parameters for these stations during 1981 (Table 5-22) were similar to 1980 observations:

Parameter	1981 Mean	1980 Mean
TDS	845	836
Alkalinity	399	432
Calcium	112	104
Magnesium	63	66
Sodium	91	94
Bicarbonate	446	506
Sulfate	308	308

Table 5-22. Summary of Water Quality Data for Springs and Seeps, Lurgi Plant Site Program, 1981

TYPE=SEEP AREA=CONTROL REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	16	7.88	0.37	8.90	7.30	7.30	8.90
CONDUCTIVITY	16	1035.31	87.38	1175.00	900.00	900.00	1175.00
TOT DIS SOLIDS	6	845.33	88.85	958.00	753.00	753.00	958.00
ALKALINITY	8	399.00	48.31	479.00	342.00	342.00	479.00
CALCIUM	6	111.50	25.76	144.00	85.00	85.00	144.00
MAGNESIUM	6	63.33	6.35	73.00	56.00	56.00	73.00
POTASSIUM	6	1.23	0.55	1.92	0.58	0.58	1.92
SODIUM	6	90.83	17.29	125.00	77.00	77.00	125.00
BICARBONATE	8	445.50	49.29	526.00	379.00	379.00	526.00
CARBONATE	1	1.21	.	1.21	1.21	1.21	1.21
CHLORIDE	6	10.38	3.00	15.80	7.95	7.95	15.80
NITRATE	5	1.08	0.23	1.30	0.70	0.70	1.30
SULFATE	6	308.33	63.68	397.00	238.00	238.00	397.00
FLUORIDE	6	0.26	0.07	0.35	0.17	0.17	0.35
AMMONIA	3	1.01	0.33	1.40	0.82	0.82	1.40
PHOSPHATE	4	0.07	0.04	0.10	0.02	0.02	0.10
BORON	6	0.24	0.10	0.38	0.13	0.13	0.38
SILICA	6	20.50	3.39	24.00	15.00	15.00	24.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	14	7.43	4.20	17.00	3.00	3.00	17.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	0	.	.	.	.	.	.
ALUMINUM	1	0.40	.	0.40	0.40	0.40	0.40
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	3	0.04	0.03	0.06	0.01	0.01	0.06
MANGANESE	1	0.03	.	0.03	0.03	0.03	0.03
NICKEL	0	.	.	.	.	.	.
STRONTIUM	3	1.23	0.09	1.31	1.13	1.13	1.31
TITANIUM	0	.	.	.	.	.	.
ZINC	1	0.01	.	0.01	0.01	0.01	0.01
ZIRCONIUM	0	.	.	.	.	.	.

No appreciable temporal trends are indicated by these data.

2. Alluvial Aquifers

a. Field Data - Field data from Lurgi plant site monitoring are presented in Appendix 5-3.1. Water levels in 1981 at control station GS-S24 were somewhat deeper than observed in recent years, indicating relatively dry conditions. For example, the maximum water level (depth to water) during 1981 (Figure 5-14) was 10.1 feet while the maximum depths for 1979 and 1980 were 8.8 and 8.9 feet, respectively. The mean conductivity for GS-S24 in 1981 (Figure 5-15) was elevated over recent years, which may also be a reflection of the drop in water level and subsequent higher concentration of salts in the alluvium. The 1980 pH and water temperature measurements were similar to earlier observations.

Field data collected at Lurgi site near-field alluvial wells during 1981 (Table 5-23) were similar to data collected in 1977, the last year when field surveys were completed. These data are for wells GS-S22 and GS-S23, as other near-field wells have been dry since they were installed:

Parameter	Mean		Maximum	
	1981	1977	1981	1977
Water level (feet)	46.1	49.2	56.8	72.5
Temperature (°C)	9.9	9.7	11.5	11.3
Conductivity (micromhos/cm)	1641	1603	2400	2000
pH	7.9	6.6	8.4	6.8

The one exception is pH, which has increased appreciably since the 1977 surveys.

Far-field alluvial stations exhibited lower water levels during 1981 than during earlier years; however, field-measured water quality was generally comparable.

Table 5-23. Summary of Field Data from Alluvial Wells, Lurgi Plant Site Program, 1981

TYPE=ALUV AREA=CONTROL REPORT YEAR=1981

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
WATER LEVEL	107	9.21	0.15	10.10	8.60	9.10	9.30
TEMPERATURE	7	9.01	0.90	10.00	8.00	8.00	10.00
CONDUCTIVITY	7	1860.71	67.48	1950.00	1775.00	1775.00	1950.00
PH	8	6.66	2.45	7.70	0.60	0.60	7.70

TYPE=ALUV AREA=NEAR FIELD REPORT YEAR=1981

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
WATER LEVEL	34	46.11	9.16	56.80	36.60	36.60	56.50
TEMPERATURE	32	9.89	0.98	11.50	7.70	8.02	11.43
CONDUCTIVITY	32	1640.59	376.04	2400.00	1150.00	1150.00	2400.00
PH	32	7.89	0.30	8.40	7.50	7.50	8.40

TYPE=ALUV AREA=FAR FIELD REPORT YEAR=1981

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
WATER LEVEL	28	18.18	11.18	30.00	4.70	4.83	29.91
TEMPERATURE	13	10.42	4.13	16.50	6.50	6.50	16.50
CONDUCTIVITY	13	2814.62	244.66	3300.00	2475.00	2475.00	3300.00
PH	13	7.37	0.13	7.60	7.20	7.20	7.60

b. Water Quality Data - Water quality data from the Lurgi plant site monitoring are presented in Appendix 5-3.2. The increased conductivity relative to earlier years that was indicated for the alluvial control well GS-S24 for 1981 (Table 5-24) was also reflected in the water chemistry data (no water chemistry data were collected at GS-S24 during 1980):

Parameter	1981 Mean	1979 Mean
TDS	1508	1270
Alkalinity	598	486
Calcium	133	102
Magnesium	138	100
Sodium	170	163
Bicarbonate	627	595
Sulfate	688	500

Water chemistry data for GS-S24 was not collected during 1980.

Water quality during 1981 at near-field alluvial wells for the Lurgi plant site (Table 5-25) exhibited appreciable increases in mean total dissolved solids (TDS) compared to earlier years (2051 mg/l versus 1379 and 1420 mg/l in 1977 and 1976 respectively). The change was due to moderate increases in most major ions and large increases in mean sulfate levels (923 mg/l in 1981 versus 594 and 597 mg/l in 1977 and 1976, respectively). Water chemistry was not monitored at these near-field stations during the 1978-1980 period.

The mean concentrations of most major water quality constituents at the far-field alluvial wells (Table 5-26) decreased in 1981 as compared to 1980 (the only other year of record):

Parameter	1981 Mean	1980 Mean
Alkalinity	643	861
Calcium	145	113
Magnesium	173	288
Sodium	322	411
Bicarbonate	755	1007
Sulfate	1086	1535

Table 5-24. Summary of Water Quality Data for Alluvial Control Wells, Lurgi Plant Site Program, 1981

TYPE=ALUV AREA=CONTROL REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	3	7.40	0.36	7.70	7.00	7.00	7.70
CONDUCTIVITY	3	1691.67	87.80	1975.00	1800.00	1800.00	1975.00
TOT DIS SOLIDS	3	1508.33	65.55	1584.00	1469.00	1469.00	1584.00
ALKALINITY	3	598.33	113.17	729.00	532.00	532.00	729.00
CALCIUM	3	132.67	15.53	150.00	120.00	120.00	150.00
MAGNESIUM	3	137.67	19.66	160.00	123.00	123.00	160.00
POTASSIUM	3	2.00	0.34	2.40	1.78	1.78	2.40
SODIUM	3	170.00	10.00	180.00	160.00	160.00	180.00
BICARBONATE	3	627.67	6.66	635.00	622.00	622.00	635.00
CARBONATE	1	1.00	.	1.00	1.00	1.00	1.00
CHLORIDE	3	18.93	1.69	20.10	17.00	17.00	20.10
NITRATE	3	0.80	0.56	1.30	0.20	0.20	1.30
SULFATE	3	688.33	52.00	746.00	645.00	645.00	746.00
FLUORIDE	3	0.18	0.12	0.32	0.11	0.11	0.32
AMMONIA	3	0.72	0.73	1.50	0.06	0.06	1.50
PHOSPHATE	3	0.05	0.05	0.10	0.01	0.01	0.10
BORON	3	0.74	1.01	1.90	0.14	0.14	1.90
SILICA	3	20.33	1.15	21.00	19.00	19.00	21.00
IRON	1	0.05	.	0.05	0.05	0.05	0.05
DIS ORG CARBON	3	16.00	14.00	32.00	6.00	6.00	32.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	1	0.10	.	0.10	0.10	0.10	0.10
MERCURY	0	.	.	.	.	.	.
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	1	0.90	.	0.90	0.90	0.90	0.90
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	1	0.14	.	0.14	0.14	0.14	0.14
COPPER	1	0.02	.	0.02	0.02	0.02	0.02
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	1	0.03	.	0.03	0.03	0.03	0.03
MANGANESE	0	.	.	.	.	.	.
NICKEL	0	.	.	.	.	.	.
STRONTIUM	1	2.64	.	2.64	2.64	2.64	2.64
TITANIUM	0	.	.	.	.	.	.
ZINC	1	0.05	.	0.05	0.05	0.05	0.05
ZIRCONIUM	0	.	.	.	.	.	.

Table 5-25. Summary of Water Quality Data for Alluvial Near-Field Wells, Lurgi Plant Site Program, 1981

TYPE=ALUV AREA=NEAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	2	7.70	0.14	7.80	7.60	7.60	7.80
CONDUCTIVITY	2	2375.00	35.36	2400.00	2350.00	2350.00	2400.00
TOT DIS SOLIDS	2	2051.00	140.01	2150.00	1952.00	1952.00	2150.00
ALKALINITY	2	614.00	7.07	619.00	609.00	609.00	619.00
CALCIUM	2	81.00	8.49	87.00	75.00	75.00	87.00
MAGNESIUM	2	175.00	7.07	180.00	170.00	170.00	180.00
POTASSIUM	2	1.81	0.19	1.95	1.68	1.68	1.95
SODIUM	2	290.00	28.28	310.00	270.00	270.00	310.00
BICARBONATE	2	722.00	5.66	726.00	718.00	718.00	726.00
CARBONATE	0	.	.	.	.	.	.
CHLORIDE	2	27.95	2.90	30.00	25.90	25.90	30.00
NITRATE	2	0.60	0.28	0.80	0.40	0.40	0.80
SULFATE	2	923.00	89.10	986.00	860.00	860.00	986.00
FLUORIDE	2	0.43	0.06	0.48	0.39	0.39	0.48
AMMONIA	2	0.74	0.57	1.14	0.34	0.34	1.14
PHOSPHATE	2	0.15	0.11	0.23	0.07	0.07	0.23
BORON	2	0.30	0.22	0.46	0.15	0.15	0.46
SILICA	2	28.50	3.54	31.00	26.00	26.00	31.00
IRON	0	.	.	.	.	.	.
DIS ORG CARBON	2	7.00	4.24	10.00	4.00	4.00	10.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	2	2.55	1.91	3.90	1.20	1.20	3.90
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	1	0.04	.	0.04	0.04	0.04	0.04
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	1	0.03	.	0.03	0.03	0.03	0.03
MANGANESE	0	.	.	.	.	.	.
NICKEL	0	.	.	.	.	.	.
STRONTIUM	1	3.14	.	3.14	3.14	3.14	3.14
TITANIUM	0	.	.	.	.	.	.
ZINC	1	0.03	.	0.03	0.03	0.03	0.03
ZIRCONIUM	0	.	.	.	.	.	.

Table 5-26. Summary of Water Quality Data for Alluvial Far-Field Wells, Lurgi Plant Site Program, 1981

TYPE=ALUV AREA=FAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	6	7.45	0.20	7.80	7.20	7.20	7.80
CONDUCTIVITY	6	2566.67	378.03	2990.00	1950.00	1950.00	2990.00
TOT DIS SOLIDS	6	2166.17	404.40	2568.00	1468.00	1468.00	2568.00
ALKALINITY	6	642.50	54.46	751.00	602.00	602.00	751.00
CALCIUM	6	144.83	35.85	200.00	91.00	91.00	200.00
MAGNESIUM	6	173.33	34.98	210.00	118.00	118.00	210.00
POTASSIUM	6	3.19	1.28	4.80	1.42	1.42	4.80
SODIUM	6	321.67	74.14	410.00	240.00	240.00	410.00
BICARBONATE	6	754.67	60.77	876.00	708.00	708.00	876.00
CARBONATE	2	1.00	0.00	1.00	1.00	1.00	1.00
CHLORIDE	6	28.40	5.73	33.50	18.40	18.40	33.50
NITRATE	5	0.16	0.09	0.30	0.10	0.10	0.30
SULFATE	6	1086.00	247.15	1315.00	625.00	625.00	1315.00
FLUORIDE	6	0.20	0.14	0.39	0.10	0.10	0.39
AMMONIA	6	3.60	5.37	13.40	0.05	0.05	13.40
PHOSPHATE	6	0.47	1.03	2.57	0.01	0.01	2.57
BORON	6	0.39	0.21	0.66	0.22	0.22	0.66
SILICA	6	23.50	2.43	28.00	21.00	21.00	28.00
IRON	2	0.05	0.00	0.05	0.05	0.05	0.05
DIS ORG CARBON	6	14.83	9.75	33.00	7.00	7.00	33.00
ARSENIC	1	0.01	.	0.01	0.01	0.01	0.01
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	2	0.70	0.14	0.80	0.60	0.60	0.80
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	2	0.45	0.35	0.70	0.20	0.20	0.70
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	2	0.03	0.01	0.04	0.03	0.03	0.04
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	3	0.04	0.01	0.05	0.03	0.03	0.05
MANGANESE	3	0.26	0.33	0.64	0.04	0.04	0.64
NICKEL	0	.	.	.	.	.	.
STRONTIUM	3	3.72	0.66	4.46	3.21	3.21	4.46
TITANIUM	0	.	.	.	.	.	.
ZINC	3	0.03	0.02	0.05	0.02	0.02	0.05
ZIRCONIUM	0	.	.	.	.	.	.

As expected, the concentrations of dissolved constituents in alluvial wells monitored for the Lurgi plant site program generally increase in the downgradient direction (control to near-field to far-field). Mean concentrations at near- and far-field alluvial wells were fairly similar during 1981 while concentrations at the control well were appreciably lower than either of the other two station groupings. A similar, though less consistent spatial pattern of concentrations was noted for 1981 maximum concentrations at the control, near-field, and far-field sites.

c. Statistical Analysis - The MANOVA of the Lurgi plant site alluvial aquifer monitoring data indicated significant variability for the area (station type) main effect for all of the selected constituents except fluoride. Significant variability for the year main effect was observed for all constituents but calcium, sodium, fluoride, and chloride:

	Probability > F		
Parameter	Area	Year	Area x Year
TDS	.0001	.0001	.0499
Conductivity	.0001	.0007	.0440
pH	.0001	.0001	.5110
Alkalinity	.0001	.0002	.9573
Calcium	.0004	.0624	.2780
Magnesium	.0001	.0049	.4115
Sodium	.0001	.2619	.1032
Fluoride	.1115	.0592	.6158
Chloride	.0090	.6052	.5474
Bicarbonate	.0001	.0101	.8097
Sulfate	.0001	.0001	.4139

The interaction term (area x year) was nonsignificant for all constituents at the 0.05 level except TDS and conductivity, which were only slightly significant for these two constituents. The overall effects tests (Hotelling-Lawley trace, Pillai's trace, and Wilks' Criterion) were all highly significant (Pr > F=.0001) for both the area (station type) and year main effects (Appendix 5-3.3). The probability statistic for Roy's Maximum Root Criterion

could not be calculated for either the area (station type) or the year main effect, due to the very nonsignificant probabilities observed for fluoride (area main effect) and sodium and chloride (year main effect).

The Duncan's Multiple Range Test for the area (station type) main effect showed two patterns. For TDS, conductivity, magnesium, bicarbonate, and sulfate ions, all three areas (control, near-field, and far-field) were significantly different. For pH, alkalinity, calcium, sodium, and chloride, the control and near-field groupings were not significantly different but were different from the far-field stations. The means for the station type groupings were as follows:

Parameter	Control	Near-Field	Far-Field
TDS	1255	1423	2166
Conductivity	1680	1812	2567
pH	6.6	6.5	7.5
Alkalinity	495	419	643
Calcium	94	83	145
Magnesium	106	130	173
Sodium	190	210	322
Chloride	17	20	28
Bicarbonate	586	624	755
Sulfate	508	593	1086

Fluoride was not included in this evaluation because of the non-significant area variability. The above data illustrate the general increasing trend in dissolved constituents in the downstream direction.

Duncan's Multiple Range Tests for the year main effect yielded the following:

Parameter	Years Significantly Different from 1981
TDS	1975, 1976, 1977, 1978, 1979
Conductivity	1975, 1976, 1977, 1978, 1979
pH	1975, 1976, 1977
Alkalinity	1975, 1976, 1977, 1978
Magnesium	1975, 1976, 1978, 1979
Bicarbonate	1975, 1976, 1977, 1978
Sulfate	1975, 1976, 1977, 1978, 1979

Most of these increases are the result of data from the 1981 sampling of the far-field stations (GS-S28, GS-S29, and GS-S30 series), which exhibit appreciably higher levels of major inorganics than the near-field tract wells during the 1975-79 period.

4. Upper Aquifer

a. Field Data - Field data for 1981 for upper aquifer control wells for the Lurgi plant site program were generally comparable to 1980 observations. Water levels were somewhat shallower than observed in 1979 and 1980. Water temperatures and pH have remained fairly constant over recent years, while conductivity has increased:

	Mean			Maximum		
Parameter	1981	1980	1979	1981	1980	1979
Water level (feet)	515	624	641	608	656	656
Conductivity (micromhos/cm)	1488	1404	1293	1825	1700	1575

Water levels for 1981 for control well GS-M7U are shown in Figure 5-30.

Field data available for 1980 and 1981 for near-field upper aquifer wells show slight increases in depth-to-water (average about 10 feet), conductivity (average about 478 micromhos/cm) and pH (about 0.5 pH units). Except for the water level data, only one field data observation was made in 1980. Thus

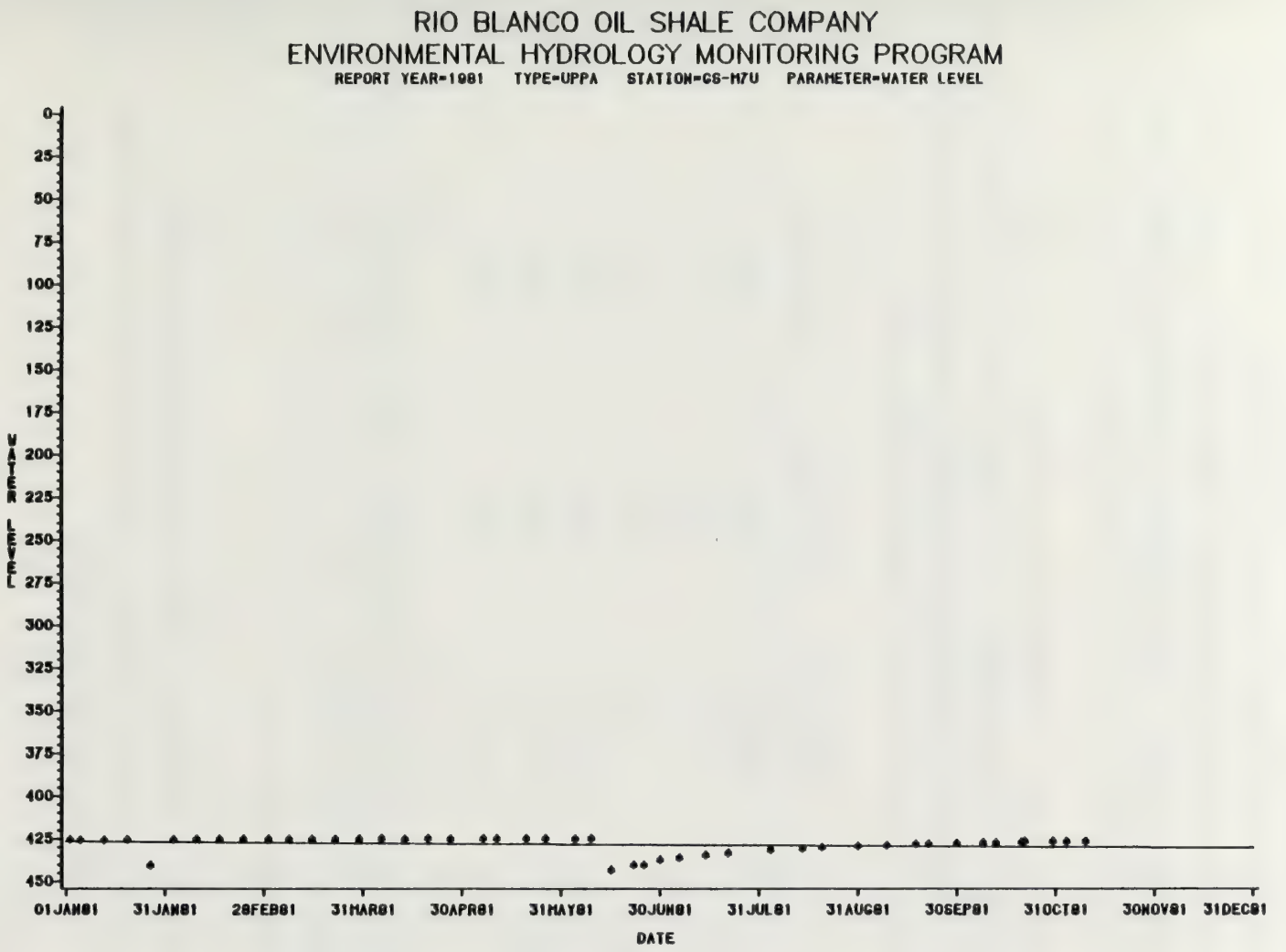


Figure 5-30. Water Level (Depth to Water, Feet) in Upper Aquifer Well GS-M7U During 1981

trend evaluation is indeterminate. Water levels for near-field well GS-M8U are shown in Figure 5-31.

Mean water levels, temperature and pH in far-field upper aquifer wells during 1981 were similar to those of 1980. However, the mean specific conductance for 1981 (2058 micromhos/cm) was appreciably greater than the mean of 1402 micromhos/cm observed in 1980. This increase in conductivity was largely caused by a single observation of 3300 micromhos/cm at well GS-M5U in 1981.

b. Water Quality Data - The 1981 mean concentrations of most inorganic constituents in upper aquifer control wells (Table 5-27) were slightly higher than 1980 means. Decreases in sodium and sulfate concentrations resulted in an overall decrease in the mean total dissolved solids level:

Parameter	1981 Mean	1980 Mean	1976 Mean
TDS	1034	1118	825
Alkalinity	417	403	320
Calcium	71	68	32
Magnesium	55	50	32
Sodium	206	240	243
Bicarbonate	486	469	373
Sulfate	434	462	318

The concentrations of all of these constituents except sodium have increased considerably since the baseline period (1976). To a large extent, this reflects the process of equilibration in deep aquifer wells rather than the effects of development activities.

Water quality data from sampling of near-field upper aquifer wells (Table 5-28) exhibited a general increase in concentrations of many major inorganic ions in 1981 as compared to 1980:

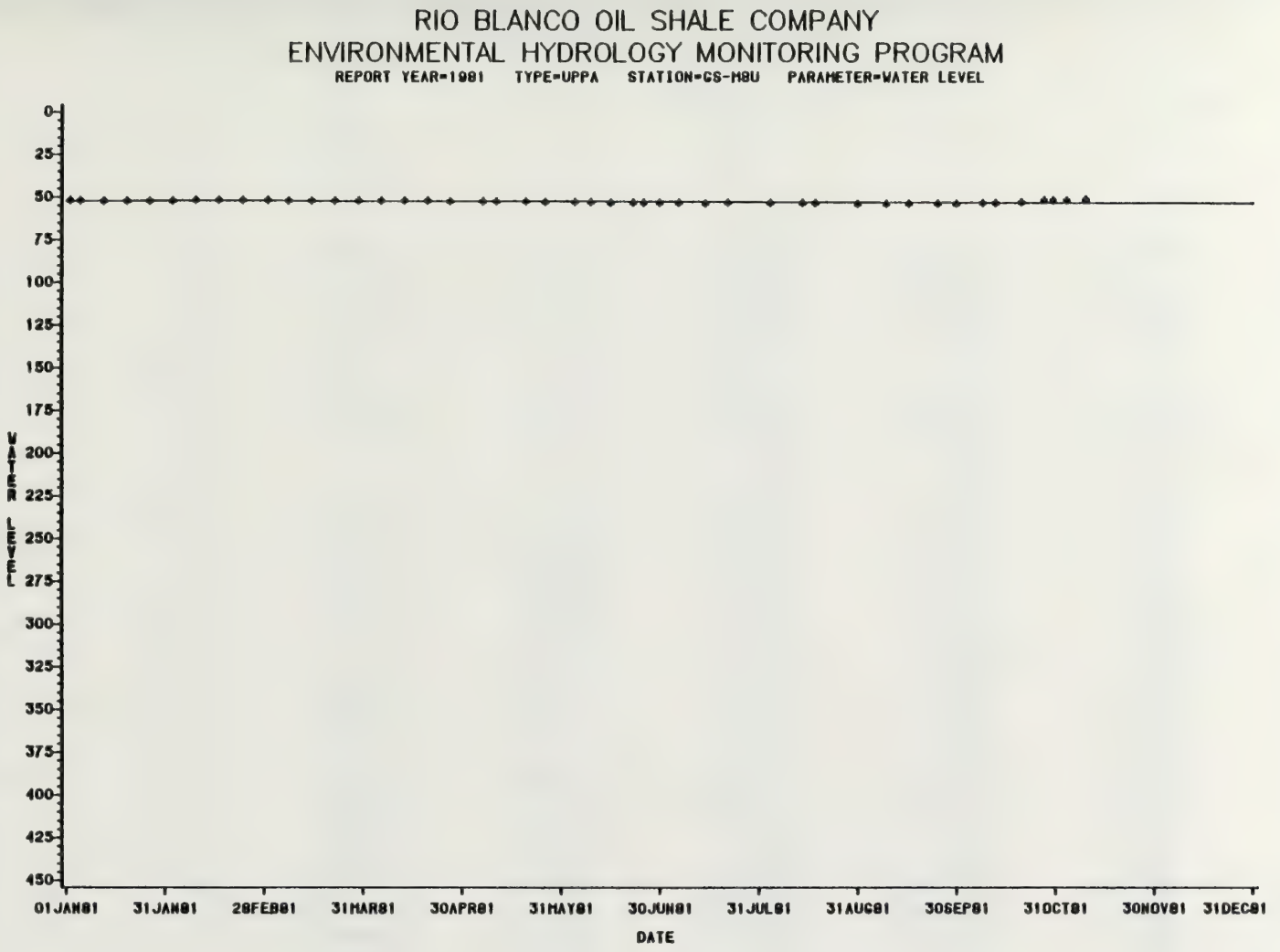


Figure 5-31. Water Level (Depth to Water, Feet) in Upper Aquifer Well GS-M8U During 1981

Table 5-27. Summary of Water Quality Data for Upper Aquifer Control Wells, Lurgi Plant Site Program, 1981

TYPE=UPPA AREA=CONTROL REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	8	7.61	0.26	8.00	7.10	7.10	8.00
CONDUCTIVITY	9	1201.67	563.13	1725.00	-200.00	-200.00	1725.00
TOT DIS SOLIDS	9	1033.67	244.03	1378.00	828.00	828.00	1378.00
ALKALINITY	9	417.33	85.21	532.00	324.00	324.00	532.00
CALCIUM	9	70.56	45.73	134.00	37.00	37.00	134.00
MAGNESIUM	9	54.56	28.97	95.00	32.00	32.00	95.00
POTASSIUM	9	0.62	0.08	0.70	0.49	0.49	0.70
SODIUM	9	206.00	29.73	260.00	170.00	170.00	260.00
BICARBONATE	9	486.22	103.54	626.00	372.00	372.00	626.00
CARBONATE	1	1.00	.	1.00	1.00	1.00	1.00
CHLORIDE	9	10.01	2.74	15.10	6.09	6.09	15.10
NITRATE	3	0.17	0.06	0.20	0.10	0.10	0.20
SULFATE	9	434.33	118.72	647.00	340.00	340.00	647.00
FLUORIDE	9	0.13	0.08	0.27	0.05	0.05	0.27
AMMONIA	6	0.34	0.47	1.20	0.04	0.04	1.20
PHOSPHATE	7	0.03	0.03	0.07	0.01	0.01	0.07
BORON	8	0.19	0.09	0.32	0.07	0.07	0.32
SILICA	8	24.25	9.77	40.00	12.00	12.00	40.00
IRON	2	0.12	0.10	0.19	0.05	0.05	0.19
DIS ORG CARBON	8	5.38	2.67	10.00	3.00	3.00	10.00
ARSENIC	2	0.01	0.01	0.02	0.01	0.01	0.02
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	2	0.45	0.07	0.50	0.40	0.40	0.50
MERCURY	1	3.10	.	3.10	3.10	3.10	3.10
ALUMINUM	1	0.10	.	0.10	0.10	0.10	0.10
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	1	0.80	.	0.80	0.80	0.80	0.80
CADMIUM	1	0.01	.	0.01	0.01	0.01	0.01
CHROMIUM	0	.	.	.	.	.	.
COPPER	1	0.02	.	0.02	0.02	0.02	0.02
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	2	0.09	0.01	0.10	0.09	0.09	0.10
MANGANESE	3	0.03	0.01	0.04	0.02	0.02	0.04
NICKEL	1	0.13	.	0.13	0.13	0.13	0.13
STRONTIUM	3	2.74	0.34	3.07	2.40	2.40	3.07
TITANIUM	0	.	.	.	.	.	.
ZINC	3	0.02	0.02	0.04	0.01	0.01	0.04
ZIRCONIUM	0	.	.	.	.	.	.

Table 5-28. Summary of Water Quality Data for Upper Aquifer Near-Field Wells, Lurgi Plant Site Program, 1981

TYPE=UPPA AREA=NEAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	5	7.86	0.27	8.30	7.60	7.60	8.30
CONDUCTIVITY	6	1291.67	742.74	1825.00	-200.00	-200.00	1825.00
TOT DIS SOLIDS	6	1125.33	117.47	1352.00	1032.00	1032.00	1352.00
ALKALINITY	6	628.17	89.50	725.00	515.00	515.00	725.00
CALCIUM	6	42.83	9.95	57.00	30.00	30.00	57.00
MAGNESIUM	6	84.17	20.05	120.00	71.00	71.00	120.00
POTASSIUM	6	0.73	0.11	0.91	0.58	0.58	0.91
SODIUM	6	240.00	22.80	270.00	220.00	220.00	270.00
BICARBONATE	6	733.33	111.68	833.00	579.00	579.00	833.00
CARBONATE	2	1.15	0.17	1.27	1.03	1.03	1.27
CHLORIDE	6	7.72	2.06	9.92	4.59	4.59	9.92
NITRATE	3	0.23	0.12	0.30	0.10	0.10	0.30
SULFATE	6	374.00	67.85	453.00	280.00	280.00	453.00
FLUORIDE	6	0.18	0.13	0.38	0.05	0.05	0.38
AMMONIA	5	0.33	0.35	0.80	0.06	0.06	0.80
PHOSPHATE	5	0.04	0.03	0.07	0.01	0.01	0.07
BORON	6	0.24	0.23	0.69	0.01	0.01	0.69
SILICA	6	22.00	9.61	34.00	7.00	7.00	34.00
IRON	1	0.05	.	0.05	0.05	0.05	0.05
DIS ORG CARBON	4	5.00	2.94	8.00	2.00	2.00	8.00
ARSENIC	1	0.01	.	0.01	0.01	0.01	0.01
SELENIUM	1	0.01	.	0.01	0.01	0.01	0.01
VANADIUM	1	0.50	.	0.50	0.50	0.50	0.50
MOLYBDENUM	1	0.10	.	0.10	0.10	0.10	0.10
MERCURY	2	0.85	0.78	1.40	0.30	0.30	1.40
ALUMINUM	2	0.20	0.14	0.30	0.10	0.10	0.30
BARIUM	1	0.10	.	0.10	0.10	0.10	0.10
BERYLLIUM	1	0.01	.	0.01	0.01	0.01	0.01
BISMUTH	1	0.01	.	0.01	0.01	0.01	0.01
BROMIDE	2	0.50	0.42	0.80	0.20	0.20	0.80
CADMIUM	2	0.02	0.01	0.03	0.01	0.01	0.03
CHROMIUM	1	0.01	.	0.01	0.01	0.01	0.01
COPPER	2	0.02	0.01	0.03	0.01	0.01	0.03
GALLIUM	1	0.50	.	0.50	0.50	0.50	0.50
GERMANIUM	1	0.10	.	0.10	0.10	0.10	0.10
LEAD	1	0.10	.	0.10	0.10	0.10	0.10
LITHIUM	4	0.15	0.10	0.24	0.06	0.06	0.24
MANGANESE	3	0.05	0.03	0.08	0.02	0.02	0.08
NICKEL	1	0.05	.	0.05	0.05	0.05	0.05
STRONTIUM	4	6.37	5.99	14.10	1.47	1.47	14.10
TITANIUM	1	0.50	.	0.50	0.50	0.50	0.50
ZINC	4	0.02	0.01	0.04	0.01	0.01	0.04
ZIRCONIUM	1	10.00	.	10.00	10.00	10.00	10.00

Parameter	1981 Mean	1980 Mean
TDS	1125	932
Alkalinity	628	583
Calcium	43	49
Magnesium	84	65
Sodium	240	210
Bicarbonate	733	694
Sulfate	374	243

The increase is due largely to sodium, magnesium, and sulfate concentrations.

The mean concentrations of most major inorganics observed in 1981 at far-field upper aquifer wells (Table 5-29) were generally similar to or lower than 1980 mean concentrations:

Parameter	1981 Mean	1980 Mean	1976 Mean
TDS	1005	1063	1362
Alkalinity	522	590	506
Calcium	5	11	70
Magnesium	77	86	108
Sodium	234	233	258
Bicarbonate	336	429	584
Sulfate	477	385	623

The concentrations observed in 1980 and 1981 are appreciably lower than means observed during the baseline (1976). The decline is exhibited mostly in concentrations of calcium, magnesium, bicarbonate, and sulfate.

No consistent spatial trends were apparent in the 1981 mean and maximum concentrations observed. The near-field upper aquifer wells exhibited the highest mean TDS due to relatively high alkalinity (bicarbonate) levels. However, the near-field wells had the lowest mean sulfate concentration during 1981. Concentrations of magnesium and sodium were fairly similar across the three types of wells, but calcium concentrations decreased along the control -- near-field -- far-field gradient.

Table 5-29. Summary of Water Quality Data for Upper Aquifer Far-Field Wells, Lurgi Plant Site Program, 1981

TYPE=UPPA AREA=FAR FIELD REPORT YEAR=1981

BASIC AND TRACE WATER QUALITY CONSTITUENTS

PARAMETER	N	MEAN	STD	MAX	MIN	P5	P95
PH	10	9.53	0.17	9.80	9.20	9.20	9.80
CONDUCTIVITY	10	1391.00	96.75	1575.00	1275.00	1275.00	1575.00
TOT DIS SOLIDS	10	1005.30	118.43	1180.00	780.00	780.00	1180.00
ALKALINITY	10	522.20	73.97	679.00	434.00	434.00	679.00
CALCIUM	10	4.72	0.78	5.80	3.70	3.70	5.80
MAGNESIUM	10	76.60	29.58	120.00	48.00	48.00	120.00
POTASSIUM	10	3.05	1.96	6.80	1.26	1.26	6.80
SODIUM	10	234.10	30.13	270.00	198.00	198.00	270.00
BICARBONATE	10	336.30	73.71	464.00	254.00	254.00	464.00
CARBONATE	10	13.81	2.71	17.40	9.61	9.61	17.40
CHLORIDE	10	15.95	5.62	25.20	7.21	7.21	25.20
NITRATE	2	0.10	0.00	0.10	0.10	0.10	0.10
SULFATE	10	476.90	99.96	660.00	312.00	312.00	660.00
FLUORIDE	10	0.44	0.48	1.56	0.03	0.03	1.56
AMMONIA	7	1.12	0.97	2.78	0.20	0.20	2.78
PHOSPHATE	9	0.08	0.03	0.13	0.01	0.01	0.13
BORON	8	0.23	0.21	0.68	0.01	0.01	0.68
SILICA	8	1.75	0.85	3.00	0.50	0.50	3.00
IRON	2	0.05	0.00	0.05	0.05	0.05	0.05
DIS ORG CARBON	10	6.70	3.74	12.00	1.00	1.00	12.00
ARSENIC	0	.	.	.	.	.	.
SELENIUM	0	.	.	.	.	.	.
VANADIUM	0	.	.	.	.	.	.
MOLYBDENUM	0	.	.	.	.	.	.
MERCURY	0	.	.	.	.	.	.
ALUMINUM	0	.	.	.	.	.	.
BARIUM	0	.	.	.	.	.	.
BERYLLIUM	0	.	.	.	.	.	.
BISMUTH	0	.	.	.	.	.	.
BROMIDE	0	.	.	.	.	.	.
CADMIUM	0	.	.	.	.	.	.
CHROMIUM	0	.	.	.	.	.	.
COPPER	0	.	.	.	.	.	.
GALLIUM	0	.	.	.	.	.	.
GERMANIUM	0	.	.	.	.	.	.
LEAD	0	.	.	.	.	.	.
LITHIUM	2	0.12	0.06	0.16	0.08	0.08	0.16
MANGANESE	1	0.04	.	0.04	0.04	0.04	0.04
NICKEL	0	.	.	.	.	.	.
STRONTIUM	2	0.91	1.20	1.76	0.07	0.07	1.76
TITANIUM	0	.	.	.	.	.	.
ZINC	0	.	.	.	.	.	.
ZIRCONIUM	0	.	.	.	.	.	.

c. Statistical Analysis - The MANOVA of upper aquifer water quality data indicated significant variability for all constituents tested for the area (station type) main effect. The year main effect was significant for all constituents except calcium, magnesium, fluoride, and sulfate:

	Probability > F		
Parameter	Area	Year	Area x Year
TDS	.0006	.0164	.0095
Conductivity	.0005	.0293	.0071
pH	.0001	.0001	.0001
Alkalinity	.0001	.0001	.4283
Calcium	.0002	.5439	.0003
Magnesium	.0001	.2907	.5182
Sodium	.0163	.0163	.2349
Fluoride	.0036	.4907	.8538
Chloride	.0073	.0417	.7191
Bicarbonate	.0001	.0303	.0001
Sulfate	.0010	.0702	.0247

The interaction term (area x year) was significant for TDS, conductivity, pH, calicum, bicarbonate, and sulfate. The overall effects tests were all highly significant for both the area (station type) and year main effects. The probability statistic could not be estimated for the Roy's Maximum Root Criterion for either main effect.

Duncan's Multiple Range Tests for the area (station type) main effect showed that the near-field means were not significantly different from the control or far-field station means for TDS, conductivity, calcium, sodium, and fluoride. However, control and far-field stations were significantly different for these parameters. The observed means for the three station groupings are as follows:

Parameter	Control	Near-Field	Far-Field
TDS	972	1139	1405
Conductivity	1341	1590	1890
pH	7.4	7.9	8.0
Alkalinity	375	614	487
Calcium	55	43	29
Magnesium	43	87	85
Sodium	226	238	335
Fluoride	0.1	0.2	0.6
Chloride	13	7	17
Bicarbonate	440	714	455
Sulfate	401	393	669

An increasing trend in the downgradient direction for TDS, conductivity, pH, magnesium, sodium, fluoride, and sulfate is shown by these data. Alkalinity (and bicarbonate) exhibited maximum means in the near-field wells.

Constituents which exhibited a significant year main effect in the MANOVA were used in a Duncan's Multiple Range Test to examine the nature and significance of differences in means over years. The results are as follows:

Parameter	1975	1976	1977	1978	1979	1980	1981
TDS	1373	1738	2170	1270	1097	1076	1088
Conductivity	1840	2319	2550	1880	1500	1478	1507
pH	6.7	6.6	7.2	7.5	8.4	8.5	8.7
Alkalinity	407	393	300	400	410	522	497
Sodium	332	471	610	190	210	241	247
Chloride	16	23	18	4	15	13	12
Bicarbonate	487	464	305	475	466	457	465

The TDS, sodium, and chloride means for 1978-81 are not significantly different nor are any of the yearly means for conductivity and bicarbonate. The increasing trend over time for pH and alkalinity is as observed for other upper aquifer monitoring elements.

5.4 SUMMARY

The hydrology monitoring program collects information for several needs:

- Stipulations of the lease and conditions of approval from the OSO
- Engineering design input for mine and water handling systems
- Evaluation of the need for environmental mitigative measures
- Permit requirements

The program includes monitoring at numerous installations, including stream gaging stations, springs and seeps, erosion and sedimentation stations, alluvial and deep aquifer wells, surface impoundments, surface discharges, reinjection system, and dewatering wells. The natural hydrologic and hydrogeologic environment as well as facilities associated with tract development are monitored.

During 1981, the hydrology monitoring program was modified to focus on four proposed major development activities on Tract C-a (RBOSC 1981):

1. Dewatering/Reinjection/Discharge Program
2. MIS Modular Development Area
3. Open Pit
4. Lurgi Plant Site

The discussion of the 1981 monitoring program is divided into three sections, corresponding to above-listed items 1, 2, and 4. The development of the open pit and hence monitoring of this activity has been deferred and will not be considered in this report. The Lurgi plant site construction has also been deferred but some collection of background data was included in the 1981 monitoring effort and is considered in this report.

Hydrology monitoring stations have been classified as follows:

- Type I - control stations not expected to be influenced by a given set of development activities

- Type II - expected to exhibit direct, short-term impacts, should impacts result from development; such stations are located generally downgradient in near-field area relative to development

- Type III - expected to exhibit indirect or long-term impacts; should impacts result from development; such stations are located downgradient from development in far-field areas.

Grouping stations allows for spatial as well as temporal comparison of water quality and physical parameters. Thus "pre- and post" development levels and the "control vs potentially affected" areas can be compared.

A. Dewatering/Reinjection/Discharge Program

The dewatering/reinjection/discharge program focuses on monitoring for changes in ground water levels and surface flows. The cone of depression from the dewatering operation was relatively stable throughout 1981. Dewatering was accomplished through dewatering wells and mine sumps until late November 1981 when the use of dewatering wells was terminated. Dewatering flows were all reinjected or consumed in 1981; no water was discharged at the surface from this operation.

The mean concentrations of dissolved constituents in the composite reinjection water during 1981 were generally similar to that of 1979 and 1980. Decreased yearly maximum levels of calcium, magnesium, chloride, and sulfate were observed in 1981 relative to 1980.

Water quality monitoring for the dewatering/reinjection/discharge program focused on the upper aquifer. The mean concentrations of major inorganic parameters in upper aquifer control wells during 1981 were similar to 1980 means. However, mean levels of TDS, calcium, magnesium, bicarbonate, and

sulfate were lower in 1981 relative to 1980. Mean concentrations in near-field wells in 1981 were commonly higher than either 1980 or baseline (1976) means. Far-field mean concentrations in 1981 were similar to 1980 means for most constituents.

The MANOVA for selected upper aquifer water quality constituents indicated significant variability (at the .05 significance level) for all parameters except pH, fluoride, chloride, and bicarbonate for the area main effect. Significant variability for the year main effect was noted only for pH, magnesium, sodium, and marginally for chloride. The interaction term (area x year) was not significant for any constituents. This indicates a lack of change in the relative water quality at control, near-field, and far-field wells over time, although the variability among station types and years is highly significant for some constituents.

Duncan's Multiple Range Tests were used to examine the nature and significance of differences in mean concentrations over time (year) and space (control, near-field, and far-field) in the upper aquifer. Examination of spatial differences indicated that there were no significant differences between control and near-field means for conductivity, alkalinity, and sodium. There were no significant differences between near-field and far-field means for sodium. The analysis of means show the general increase in pH in the upper aquifer since the baseline and decrease in sodium and chloride concentrations. Recent years data have been very stable for these constituents. The changes in mean concentrations over time for magnesium and chloride are not significant.

The MANOVA related variance analyses, and the Duncan's Multiple Range Test indicated that although certain constituents vary significantly in time and space, the general pattern of water quality has not changed appreciably over time. Impact-related changes are not apparent from this analysis.

The water levels have been very uniform over the last two years of record for the lower aquifer, indicating an absence of influence from the continuing reinjection operations.

B. MIS Modular Development Area

Monitoring of the MIS Modular Development Area includes sampling of various process ponds, alluvial aquifers and deep aquifers. The focus of this sampling is on water quality.

The East Retention Pond is located adjacent to the MIS process area. Concentrations of most constituents in this pond increased appreciably in 1981 relative to 1980, a reflection of increased production activities in 1981. This is generally shown by increased conductivity from 1000-3000 micromhos/cm in the first half of 1981 to about 6000 micromhos/cm in the second half of the year. There was no discharge of this higher conductivity water.

The water quality of the eight evaporation ponds sampled during 1981 was quite variable due to variations in operations during 1981. Water was detected during 1981 in piezometers located adjacent to the evaporation ponds but the water quality data indicated that the water was probably due to precipitation rather than pond leakage.

The general water quality at alluvial control wells for the MIS monitoring program has been fairly constant since the baseline (1976). Most of the variabilty in mean concentrations is due to 1981 calcium and sulfate levels which increased relative to previous observations. Near-field alluvial wells are typically dry. Because these wells only intermittently contain water, resulting in different wells being sampled at different times, the water quality in the near-field is rather variable. Similarly, the water quality of the far-field data set has been variable in recent years. Temporal trends were not obvious in these data sets.

The concentrations for most major inorganic constituents in the MIS alluvial wells increased in the downstream direction. Typically, maximum concentrations in 1981 were observed at far-field stations. Calcium concentrations, however, were generally higher at near-field than at either far-field or control alluvial wells. This increasing trend in the downstream direction is typical for natural systems and hence no development-related effects are indicated.

The results of the alluvial aquifer MANOVA for selected water quality constituents indicated that, for most major inorganic constituents, significant variability was observed for the main effects of monitoring area or station type (control, near-field, far-field) and year. The interaction term (area x year) was significant only for TDS, pH, and sulfate. Thus, for most constituents, the spatial pattern of water quality variability has not changed significantly over time.

Duncan's Multiple Range Test results indicated that control area means were not significantly different than near-field alluvial well means for sodium and chloride. Near-field and far-field means were not significantly different for TDS, alkalinity, magnesium, chloride, bicarbonate, and sulfate. Thus, control alluvial well water quality tended to be significantly different than near-field and far-field wells.

Beyond an increasing trend in mean pH and perhaps sulfate concentrations, and a small decline in recent years in sodium concentrations, the 1981 means in the alluvial aquifers are generally consistent with earlier observations. Most of the observed changes over time, though significant statistically, do not appear to be of great magnitude nor indicative of development-induced impacts on water quality of the alluvial system.

The mean levels of most water quality parameters for upper aquifer control wells for the MIS Area monitoring program in 1981 were somewhat lower than in 1980 and somewhat higher than baseline (1976) means. The general chemical composition of upper aquifer control stations has not changed appreciably since the baseline period.

The mean concentrations of major ions in 1980 in near-field upper aquifer wells were similar to means observed in 1980, however, the means for many ions were lower than baseline (1976) values. A shift from sodium-bicarbonate to a mixed ion system is indicated. The 1981 far-field water quality was generally similar to 1980 observations.

In the upper aquifer wells monitored in 1981 for the MIS Area hydrology monitoring program, mean salinity generally decreased in the downgradient

direction (from control to near-field to far-field). This trend was mostly attributable to decreases in calcium, bicarbonate, and sulfate concentrations. No impact-related trends, such as increased concentrations in the near-field wells are apparent from these observations.

The results of the MANOVA for selected water quality constituents indicated that, for most major inorganic constituents in upper aquifer wells, significant variability is observed for the main effects of area (station type) and year. Significant variability over the MIS upper monitoring areas was observed for all tested consitutents except conductivity and sodium.

Duncan's Multiple Range Tests indicated that all three monitoring areas (station types: control, near-field, far-field) were significantly different for pH, calcium, bicarbonate, and sulfate. Control and far-field upper aquifer wells were significantly different for all constituents.

The examination of means indicated that the concentrations for control stations are generally greater than, or comparable to those for near-field and far-field wells. Exceptions to this generalization are pH and chloride concentrations, which generally increased in the downgradient direction.

The analysis also indicated an increasing trend in pH over time in the upper aquifer, and general decreases in alkalinity, sodium, fluoride, and chloride concentrations since the baseline measurements. The mean concentrations in recent years have been fairly stable, and development-related impacts are not evident.

Lower aquifer well GS-15L is included as a control station in the MIS Area hydrology monitoring program. The 1981 mean water levels, pH, and water temperature data were similar to observations for previous years. The 1981 mean TDS and alkalinity concentrations were appreciably greater than means observed in 1980. This was caused principally by increases in sodium and bicarbonate ion concentrations. These data reflect an increasing trend in concentrations of these constituents since the baseline period. The trend is probably related to upper-lower aquifer interconnections during the baseline

period. The most recent data are more characteristic of lower aquifer water quality.

C. Lurgi Plant Site

The monitoring program for the Lurgi plant site was designed to monitor the hydrologic effects of the proposed Lurgi demonstration project facilities. Construction of this facility, to be located north of Tract C-a, has been delayed. Hence, hydrological data collection and analysis is currently oriented to defining the baseline or pre-development conditions in the plant site area streams, springs, alluvial aquifers, and deep aquifers.

Four spring and seep monitoring stations function as control stations for the Lurgi plant site. The mean concentrations of water quality parameters for these stations during 1981 were similar to 1980 observations. No appreciable temporal trends are indicated by these data.

The increased conductivity relative to earlier years that was indicated for the alluvial control well GS-S24 for 1981 was also reflected in the water chemistry data (no water chemistry data were collected at GS-S24 during 1980). Water quality during 1981 at near-field alluvial wells for the Lurgi plant site exhibited appreciable increases in mean total dissolved solids compared to earlier years. The change was due to moderate increases in most major ions and large increases in mean sulfate levels. Water chemistry was not monitored at these near-field stations during the 1978-1980 period. The mean concentrations of most major water quality parameters at the far-field alluvial wells decreased in 1981 as compared to 1980 (the only other year of record).

As expected, the concentrations of dissolved constituents in alluvial wells monitored for the Lurgi plant site program generally increased in the down-gradient direction (control to near-field to far-field). The mean concentrations at near- and far-field alluvial wells were fairly similar during 1981, while concentrations at the control well were appreciably lower than either of the other two station groups.

The MANOVA of the Lurgi plant site alluvial aquifer monitoring data indicated significant variability for the area (station type) main effect for all of the selected constituents except fluoride. Significant variability for the year main effect was observed for all constituents but calcium, sodium, fluoride, and chloride. The interaction term (area x year) was nonsignificant for all constituents at the 0.05 level except TDS and conductivity and was only slightly significant for these two constituents.

Duncan's Multiple Range Tests for the area (station type) main effect showed two patterns. For TDS, conductivity, magnesium, bicarbonate, and sulfate ions, all three areas (control, near-field, and far-field) were significantly different. For pH, alkalinity, calcium, sodium, and chloride, the control and near-field groupings were not significantly different but were different from the far-field stations.

Most of the significant increases in means among the station groupings and over years are the result of 1981 sampling of the far-field stations (GS-S28, GS-S29, and GS-S30 well series) which exhibited appreciably higher levels of major inorganics than the near-field tract wells during the 1975-79 period.

The 1981 mean concentrations of most inorganic consitutents in upper aquifer control wells were slightly higher than 1980 means. Decreases in sodium and sulfate concentrations resulted in an overall decrease in the mean total dissolved solids level. The concentrations of all of these constituents except sodium have increased considerably since the baseline period (1976). To a large extent, this reflects the process of equilibration in deep aquifer wells rather than the effects of development activities.

Water quality data from sampling of near-field upper aquifer wells exhibited a general increase in concentrations of many major inorganic constituents in 1981 as compared to 1980. The increase was due largely to sodium, magnesium, and sulfate concentrations.

Mean concentrations of most constituents observed in 1981 at far-field upper aquifer wells were generally similar to or lower than 1980 mean concentrations. The concentrations observed in 1980 and 1981 were appreciably lower than the

means observed during the baseline (1976). The decline was exhibited mostly in concentrations of calcium, magnesium, bicarbonate, and sulfate.

No consistent spatial trends were apparent in the 1981 mean and maximum concentrations. The near-field upper aquifer wells exhibited the highest mean TDS due to relatively high alkalinity (bicarbonate) levels. However, the near-field wells had the lowest mean sulfate concentration during 1981. Concentrations of magnesium and sodium were fairly similar across the three types of wells, but calcium concentrations decreased along the control near-field far-field gradient.

The MANOVA of upper aquifer water quality data indicated significant variability for all constituents tested for the area (station type) main effect. The year main effect was significant for all constituents except calcium, magnesium, fluoride, and sulfate. The interaction term (area x year) was significant for TDS, conductivity, pH, calcium, bicarbonate, and sulfate.

Duncan's Multiple Range Tests for the area (station type) main effect showed that the near-field means were not significantly different from the control or far-field upper aquifer well means for TDS, conductivity, calcium, sodium, and fluoride.

An increasing trend in the downgradient direction for TDS, conductivity, pH, magnesium, sodium, flouride, and sulfate is shown by these data. Alkalinity (and bicarbonate) exhibited maximum means in the near-field wells. The TDS, sodium, and chloride means in the upper aquifer for 1978-81 are not significantly different nor are any of the yearly means for conductivity and bicarbonate. The increasing trend over time for pH and alkalinity is as observed for other upper aquifer monitoring elements.

LITERATURE CITED

Rio Blanco Oil Shale Company, 1981. Modular development phase environmental monitoring program scope of work. Gulf Oil Corp. and Standard Oil Co. (Indiana).

SECTION 6

SPECIAL STUDIES
ECOLOGICAL INTERRELATIONSHIPS

6.0 INTRODUCTION

In addition to the monitoring programs which have been reported in the previous sections of this report, RBOSC is conducting special studies in the following areas:

- Experimental Revegetation
- Toxicology
- Run-of-Mine Lysimeter
- Mule Deer Habitat Modification
- Shrub Growth Enhancement
- Range Exclosure
- Supplementary Sulfur Dioxide Monitoring Program

The activities during the 1981 reporting year in these areas are included in the Special Studies-Ecological Interrelationships section. With the exception of the toxicology and lysimeter studies, the efforts included in this section are designed to examine means of mitigating development-related impacts by examining the relationships between the components of the ecosystems involved. The end result of these studies will be an increased understanding of the feasibility of modifying one ecosystem component (such as vegetative community physical structure and phytosociology) to produce a desired effect on another ecosystem component (such as wildlife).

The toxicology studies reported in this section are being conducted to characterize the chemical and physical properties of oil shale and related materials, determine their biological activity, and develop an industrial hygiene program to mitigate or prevent worker exposure and environmental hazards at the RBOSC project site. The run-of-mine lysimeter study is designed to examine the leaching behavior of raw oil shale piles in field conditions, to determine the quality of leachate from such piles, and to compare the quality of such field-generated leachates to that of laboratory-generated leachates.

6.1 REVEGETATION

A. Experimental Revegetation on Surface Disturbed Sites

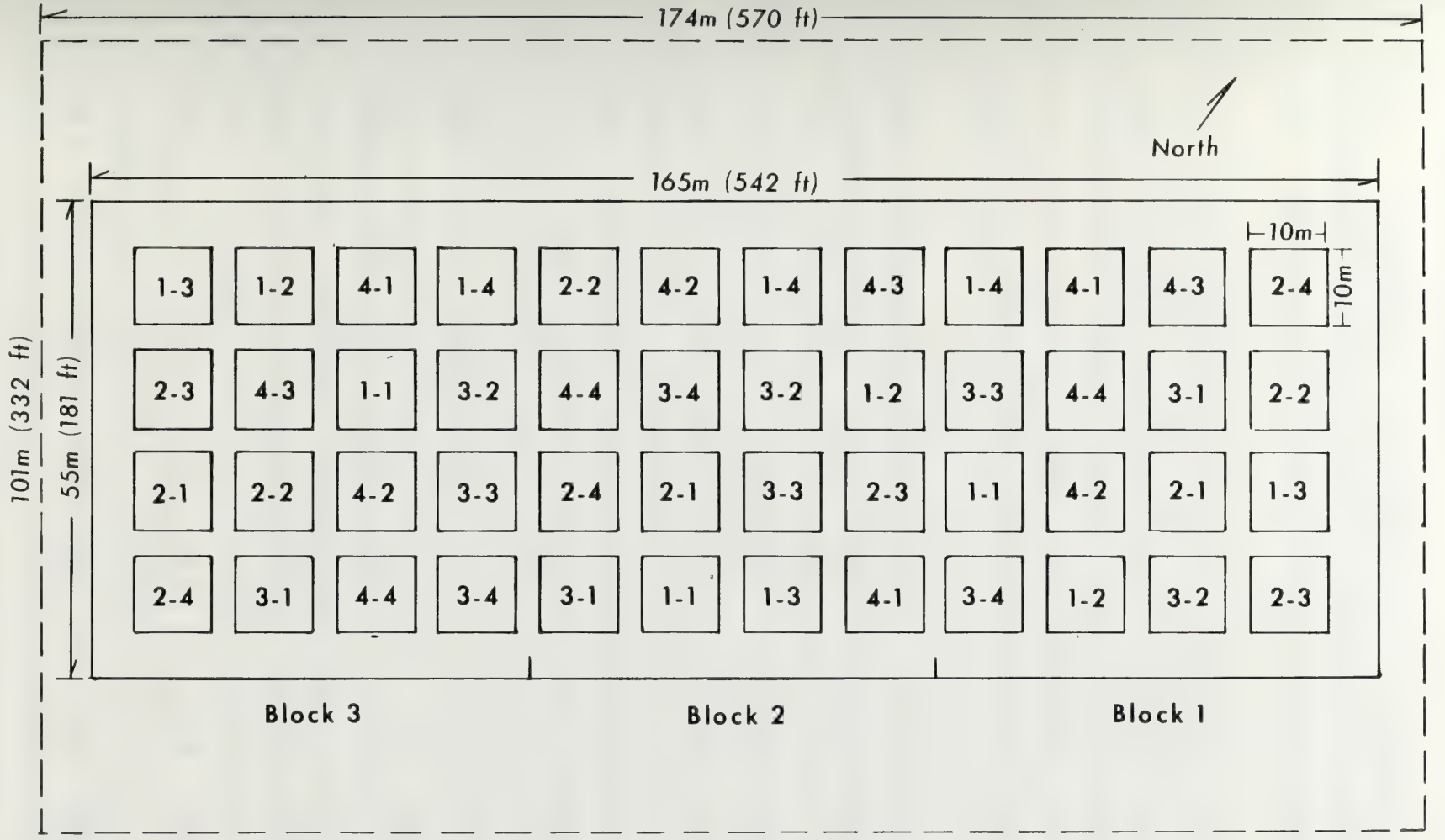
1. Objectives

The development of oil shale facilities on Tract C-a will result in disturbed lands which will be revegetated once disturbance ceases. Experiments were initiated during 1975 to demonstrate reclamation feasibility and species adaptability with varying mulch types, fertilizer applications, and plot aspects.

2. Methods

Experimental plots were constructed at two locations in the southeast corner of Tract C-a; Plot R-1 was located on a northwest exposure and Plot R-2 was located on a southeastern exposure. Surface disturbance at each site included stripping topsoil and subsoil, ripping the underlying rock substrate, and then replacing the subsoil and topsoil. Subsequent to these activities, the sites were seeded, mulched, and/or fertilized using a total of 16 treatment combinations, with three replicates of each treatment applied at each site in a randomized block design. The configuration for Plot R-1 is illustrated in Figure 6-1. Additional information on methods is presented in Section 2.5.3.2 of Progress Report 4 (RBOSP 1975) and in Revegetation Annual Reports (RBOSC 1977, 1978, 1979).

Cover estimates were not made during 1979 (the year after clipping) on either Plot R-1 or R-2. During the 1980 and 1981 reporting periods, cover estimates of Plots R-1 and R-2 were made on the same quadrats where cover was estimated and standing crop was clipped in 1978. The aboveground biomass of herbaceous species was determined by clipping these quadrats during the 1981 period. Shrub species, however, were not clipped in 1981.



Seeding Rate 18 kg/ha (16 lb/acre)

Mulch Treatments: (Applied at Sowing: First Numeral in Treatment Designation)
1 = No Mulch
2 = Hydromulch
3 = Straw Mulch Followed by Crimping
4 = Straw Mulch With Netting

Fertilizer Treatments: (180 kg/ha, 10-5-5) (Second Numeral in Treatment Designation)
1 = No Fertilizer
2 = Fertilizer at Time of Sowing
3 = Fertilizer at Beginning of First Full Growing Season
4 = Fertilizer at Sowing & Beginning of First Full Growing Season

Figure 6-1. Treatment Configuration for Experimental Revegetation Plot R2, Tract C-a.

Table 6-1. Coverage of Planted and Invaded Grasses, Forbs, and Shrubs for Experimental Revegetation Plot R-1 During 1981, Tract C-a

Treatment Combination	Grasses		Forbs		Shrubs		Total Cover
	Planted	Invaded	Planted	Invaded	Planted	Invaded	
No Mulch No Fertilizer	21.8	0.3	12.1	2.9	3.3	0.8	41.2
No Mulch Fertilized at Sowing	20.2	5.2	10.0	5.0	2.6	0.8	43.8
No Mulch Fertilized First Season	23.8	2.8	6.3	3.0	3.3	0.6	39.8
No Mulch Fertilized Sowing/First	23.8	3.8	8.3	2.6	4.8	0.8	44.1
Hydromulch No Fertilizer	18.3	5.6	17.9	3.5	2.2	0.8	48.3
Hydromulch Fertilized at Sowing	19.4	1.5	15.9	3.8	4.2	1.2	46.0
Hydromulch Fertilized First Season	23.5	4.2	9.0	3.9	5.1	0.3	46.0
Hydromulch Fertilized Sowing/First	19.2	8.1	13.4	6.7	2.1	0.5	50.0
Straw Crimped No Fertilizer	20.3	0.9	7.3	7.0	3.4	0.6	39.5
Straw Crimped Fertilized at Sowing	18.6	0.7	15.2	4.5	1.7	2.7	43.4
Straw Crimped Fertilized First Season	13.1	5.5	12.3	8.3	1.2	0.3	40.7
Straw Crimped Fertilized Sowing/First	19.5	7.3	6.8	3.8	1.3	0.2	38.9
Straw with Netting No Fertilizer	27.8	1.2	2.4	1.8	1.2	0.3	34.7
Straw with Netting Fertilized at Sowing	16.2	4.2	13.6	7.5	2.8	0.6	44.9
Straw with Netting Fertilized at First Season	24.8	3.5	10.6	2.0	2.4	1.7	45.0
Straw with Netting Fertilized Sowing/First	25.5	3.5	7.3	4.2	2.4	0.9	43.8
Mean Cover	21.0	3.6	10.5	4.4	2.7	0.8	43.0

3. Results and Discussion

a. Experimental Revegetation Plot R-1 - Cover estimates and clipping of herbaceous species for biomass on Plot R-1 were accomplished July 9-29, 1981. These data are presented in their entirety in Appendix 6-1.1.

1. R-1 Cover - Cover for all species over the 16 treatment combinations ranged from 34.7 to 50.0 percent, with a mean of 43.0 percent (Table 6-1). The highest cover value was encountered on plots that were hydromulched and fertilized at the time of sowing as well as at the beginning of the first full growing season (i.e., 1976). The lowest plant cover (34.7 percent) was exhibited on those plots with straw covered by netting and no fertilization (Table 6-1).

Planted grasses accounted for 49 percent of the total cover averaged over all treatment combinations, which is slightly higher than the 46 percent recorded last year (RBOSC 1981a). The lowest planted graminoid cover value (13.1 percent) was found on plots that had the crimped straw and fertilizer applied at the beginning of the first full growing season (Table 6-1). A planted grass cover value of 27.8 percent, the highest grass coverage in Plot R-1, was obtained on plots with crimped straw mulch covered with netting and no fertilizer. The dominant planted grasses were the wheatgrass (Agropyron) species and to a lesser extent green needlegrass (Stipa viridula). Invading grasses (primarily cheatgrass (Bromus tectorum) and squirreltail (Sitanion hystrix)) accounted for 8 percent of the total coverage resulting from all treatment combinations. Coverage ranged from 0.3 to 8.1 percent, with an average of 3.6 percent for invading grasses (Table 6-1). The lowest invading grass coverage (0.3 percent) was encountered on plots with no mulch and no fertilizer, while the highest invading grass coverage (8.1 percent) was found on plots that had been hydromulched and fertilized at the time of sowing and again at the beginning of the first full growing season.

A statistical comparison of 1981 coverage data for planted grasses between treatment combinations indicates that there were no significant differences for either main or interaction effects (Table 6-2). However, when Plot R-1 grass coverage is compared over years by a one-way analysis of variance (ANOVA; Table 6-3), there were significant differences for both the planted

Table 6-2. Results of Three-way ANOVA's for Grass, Forb, and Shrub Coverage of Planted and Invaded Species for Treatment Combinations During 1981 on Experimental Revegetation Plot R-1, Tract C-a [1/]

Growth Form	Source of Variation													
	Block		Mulch		Fertilizer		Block x Mulch		Block x Fertilizer		Mulch x Fertilizer		Block x Mulch x Fertilizer	
	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]
Grasses Planted	0.07	0.9306	0.46	0.7143	0.60	0.6232	0.52	0.7934	0.31	0.9307	0.38	0.9440	0.35	0.9932
Grasses Invaded	0.73	0.4872	0.73	0.5410	0.40	0.7561	1.47	0.2038	2.87**	0.0162	4.05**	0.0005	3.51**	0.0005
Forbs Planted	3.88**	0.0233	1.04	0.3795	1.55	0.2044	0.41	0.8699	0.63	0.7075	1.63	0.1146	1.35	0.1717
Forbs Invaded	4.92**	0.0080	1.67	0.1723	0.19	0.9036	2.34	0.0323*	0.96	0.4518	2.89**	0.0029	1.74	0.0335*
Shrubs Planted	1.44	0.2430	1.90	0.1328	0.39	0.7668	0.69	0.6556	1.33	0.2516	1.79	0.0805	0.79	0.7050
Shrubs Invaded	5.14	0.0784	4.26	0.0978	14.29**	0.0133	2.85	0.1648	2.93	0.1586	6.39*	0.0449	5.06	0.0673

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Complete analyses are presented in Appendix 6-1.2.

2/ Represents the significance probability (α) associated with F.

Table 6-3. Results of One-way ANOVA Comparing Arcsine Transformed Coverage Estimates for Grasses, Forbs, and Shrubs Between 1976, 1977, 1978, 1980, and 1981 for Experimental Revegetation Plot R-1, Tract C-a[1/]

Growth Form	Source of Variation Year	
	F	PR>F [2/]
Grasses Planted	43.98**	0.0001
Grasses Invaded	6.57**	0.0001
Forbs Planted	48.12**	0.0001
Forbs Invaded	39.53**	0.0001
Shrubs Planted	9.32**	0.0001
Shrubs Invaded	0.17	0.6859

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 6-1.2.

[2/] Represents the significance probability (α) associated with F.

and invaded grass species. The Duncan's multiple range test results for planted grass coverage follow the expected trends for revegetated areas (Table 6-4). The lowest coverage on Plot R-1 was recorded in 1976, the first year after planting. Coverage has steadily increased every year thereafter; coverage was significantly higher in 1981 and 1980 than in 1978, 1977, or 1976. Invading grass coverage was similar in 1980 and 1976, but significantly greater during these years than in 1981, 1978, or 1977 (Table 6-4). One would expect that invaded species coverage would be highest when there was a large percentage of bare ground and low competition from planted species. The 1976 and 1980 data illustrate this pattern of growth. Because the area was seeded in 1975, invading species were more competitive and had substantial coverage in 1976. Through time, planted species became more competitive, resulting in a decline of the invading grasses. However, in 1978, Plot R-1 was clipped for biomass determination, thereby allowing for openings in the plant community and the resultant high 1980 invading grass coverage. Planted species have increased in coverage (i.e., become more competitive), causing the reduction of invaded grasses in 1981. Because there are no significant main or interaction effects noted for a three-way ANOVA comparing grass coverage over years (Table 6-5), no trends regarding the significant differences among years may be identified.

Planted forb coverage in 1981 accounted for 24 percent of all coverage at Plot R-1; this value is identical to that recorded in 1980. Coverage of planted forbs ranged from 2.4 to 17.9 percent, with an average of 10.5 percent (Table 6-1). The lowest planted forb coverage was encountered on plots with straw mulch covered by netting and no fertilizer, while the highest planted forb coverage was found on those plots that were hydromulched and received no fertilizer. The dominant planted forb species were Lewis flax (Linum lewisii), yellow sweetclover (Melilotus officinalis var. Madrid) and cicer milkvetch (Astragalus cicer var. Lutana). Over all treatments, invading forbs had an average coverage of 4.4 percent with a range of 1.8 to 8.3 percent (Table 6-1). Invading forbs account for 10 percent of the total coverage. Highest invading forb coverage was found on plots with crimped straw and fertilizer applied at the beginning of the first full growing season. Lowest coverage was exhibited in plots where straw mulch covered with netting and no fertilizer were used. Scarlet gilia (Ipomopsis aggregata), Douglas chaenactis (Chaenactis douglasii), and goldenweed

Table 6-4. Results of Duncan's Multiple Range Tests for Significant Differences in Arcsine Transformed Coverage Estimates for Planted (first listing) and Invaded (second listing) Grass Species Between 1976, 1977, 1978, 1980, and 1981 on Plot R-1, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=1003 MS=.0277817

GROUPING	MEAN	N	YEAR
A	0.228072	189	81
A			
A	0.210492	175	80
B	0.118019	180	78
B			
B	0.115487	206	77
C	0.044294	258	76

ALPHA LEVEL=.05 DF=197 MS=.0170209

GROUPING	MEAN	N	YEAR
A	0.137652	45	80
A			
A	0.136954	36	76
B	0.079394	71	81
C	0.018655	37	78
C			
C	0.016155	13	77

Table 6-5. Results of Three-way ANOVA's for Grass, Forb, and Shrub Coverage of Planted and Invaded Species for Treatment Combinations Between 1977, 1978, 1980, and 1981 for Experimental Revegetation Plot R-1, Tract C-a [1/]

Growth Form	Source of Variation													
	Block		Mulch		Fertilizer		Block x Mulch		Block x Fertilizer		Mulch x Fertilizer		Block x Mulch x Fertilizer	
	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]
Grasses Planted	0.22	0.8052	1.04	0.3727	1.58	0.1904	0.53	0.7857	1.01	0.4165	0.61	0.7937	0.50	0.9607
Grasses Invaded	0.20	0.8228	0.73	0.5398	0.72	0.5460	1.27	0.2729	1.00	0.4275	0.92	0.5082	0.64	0.8577
Forbs Planted	2.03	0.1320	1.88	0.1293	0.94	0.4202	0.26	0.9571	0.72	0.6321	0.57	0.8205	0.76	0.7524
Forbs Invaded	0.80	0.4518	2.36	0.0686	1.47	0.2202	0.35	0.9098	0.71	0.6387	0.60	0.8022	0.54	0.9376
Shrubs Planted	2.09	0.1248	21.66**	0.0001	2.08	0.1000	0.97	0.4445	4.79**	0.0001	0.91	0.5176	1.64*	0.0455
Shrubs Invaded	6.56*	0.0400	5.03	0.0570	18.39**	0.0039	3.56	0.0925	3.67	0.0875	7.98**	0.0171	6.33**	0.0287

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 6-1.2.

[2/] Represents the significance probability (α) associated with F.

(Haplopappus nuttallii) were the most dominant of the invading forbs encountered on Plot R-1.

The three-way ANOVA comparing 1981 forb coverage data between the different treatment combinations of Plot R-1 indicates significant main effect differences among blocks for both planted and invaded species as well as interaction effects (block x mulch, mulch x fertilizer, and block x mulch x fertilizer) for invaded species (Table 6-2). Planted forb coverage was significantly greater in Block 2 than in the remaining two blocks, whereas Block 3 exhibited significantly higher invading forb coverage (Table 6-6). Nevertheless, the reason behind the significant differences among blocks remains obscured.

The statistical comparison (one-way ANOVA) of forb coverage over years exhibited significant differences for both the planted and invaded forbs (Table 6-3). The results of the Duncan's multiple range test indicate that coverage of planted forbs was significantly higher in 1980 and 1981 than in 1977, 1976, or 1978 (Table 6-7). It is interesting to note that, as planted forb coverage increased over the years, invaded forb coverage has decreased (Table 6-7). The source of these differences is unclear since there are no significant differences noted on the statistical comparison of main and interaction effects over years (Table 6-5).

Planted shrub coverage accounted for 6 percent of the total coverage of Plot R-1; the average planted shrub coverage was equal to 2.7 percent (Table 6-1). The highest planted shrub coverage (5.1 percent) was encountered on plots that were hydromulched and fertilized at the beginning of the first full growing season. Two treatment combinations (straw crimped and fertilized at beginning of first growing season, and straw with netting and no fertilizer) had equally low coverage of planted shrubs (1.2 percent; Table 6-1). Rabbitbrush (Chrysothamnus nauseosus and C. viscidiflorus) and winterfat (Ceratoides lanata) were the most dominant planted shrub species. Invading shrub coverage ranged from 0.2 to 2.7 percent, but averaged 0.8 percent. Invading shrubs accounted for 2 percent of the total Plot R-1 coverage. Invaded shrub coverage was made up almost entirely of broom snakeweed (Gutierrezia sarothrae).

Table 6-6. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Block) in Arcsine Transformed Coverage Estimates for Planted (first listing) and Invaded (second listing) Forb Species for 1981 on Plot R-1, Tract C-a [1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=117 MS=.0175141

GROUPING	MEAN	N	BLOCK
A	0.165475	54	2
B	0.110838	51	3
B			
B	0.100042	60	1

ALPHA LEVEL=.05 DF=259 MS=8.3E-04

GROUPING	MEAN	N	BLOCK
A	0.034457	110	3
B	0.024389	105	1
B			
B	0.023054	92	2

[1/] Block configuration is illustrated on Figure 6-1.

Table 6-7. Results of Duncan's Multiple Range Tests for Significant Differences in Arcsine Transformed Coverage Estimates for Planted (first listing) and Invaded (second listing) Forb Species Between 1976, 1977, 1978, 1980, and 1981 on Plot R-1, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=793 MS=.0093039

GROUPING	MEAN	N	YEAR
A	0.140507	138	80
A			
A	0.126169	164	81
B	0.045840	170	77
B			
B	0.035087	197	76
B			
B	0.025609	129	78

ALPHA LEVEL=.05 DF=988 MS=.0854178

GROUPING	MEAN	N	YEAR
A	0.373626	105	78
B	0.253443	177	77
C	0.126761	176	76
D	0.053318	223	80
D			
D	0.027667	312	81

The statistical comparison of 1981 shrub coverage data between treatment combinations indicates no significant differences for planted shrubs but significant differences for the fertilizer main effect and mulch x fertilizer interaction effect for invaded shrub coverage (Table 6-2). Fertilizer Treatment 2 (fertilization at the time of sowing) had significantly higher invaded shrub coverage than any of the other three fertilizer treatments (Table 6-8). Since 6 years have passed since the planting of R-1, it is unclear why this significant difference related to fertilizer occurred in 1981 but not in any previous year.

The one-way ANOVA comparing shrub coverage over years exhibited significant differences for only the planted shrubs (Table 6-3). Coverage of planted shrubs was significantly lower after one year's growth (1976) than in subsequent years (Table 6-9). Using the three-way ANOVA to compare shrub coverage over 5 years, it is evident that the significant differences noted above for planted shrubs are a result of mulch (main effect) and block x fertilizer as well as block x mulch x fertilizer (interaction effects) differences (Table 6-5). Shrub coverage was significantly higher for Mulch Treatments 1 and 2 than for Treatments 4 and 3 (Table 6-10). Significant block and fertilizer main effect differences as well as significant mulch x fertilizer and block x mulch x fertilizer interaction effects were evident for invaded shrub coverage (Table 6-5). Shrub coverage on Blocks 1 and 2 was similar but significantly higher than the coverage on Block 3 (Table 6-11). As in the case of invaded forb coverage, Fertilizer Treatment 2 produced significantly higher shrub coverage than any other fertilizer treatment (Table 6-12).

2. R-1 Biomass - Total biomass for all species over the 16 different treatment combinations averaged 831.0 kg/ha (Table 6-13) and ranged from 657.5 to 995.3 kg/ha. The lowest biomass was encountered on plots with no mulch that were fertilized at the time of sowing. The highest biomass was measured on those plots with neither mulch nor fertilizer.

The goal of RBOSC revegetation activities is to return disturbed areas to plant communities which have production comparable to or greater than the predisturbance levels. One way of determining the success of revegetation plots is to compare production on the experimental plots with that of the

Table 6-8. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Fertilizer) in Arcsine Transformed Coverage Estimates for Invaded Shrubs during 1981 on Plot R-1, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=4 MS=3.6E-04

GROUPING	MEAN	N	FERTILIZ
A	0.069125	9	2
B	0.031896	11	3
B			
B	0.028012	10	4
B			
B	0.026674	12	1

[1/] Fertilizer treatment regimes are illustrated on Figure 6-1.

Table 6-9. Results of Duncan's Multiple Range Tests for Significant Differences in Arcsine Transformed Coverage Estimates for Planted Shrub Species Between 1976, 1977, 1978, 1980, and 1981 on Plot R-1, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=788 MS=.0011181

GROUPING	MEAN	N	YEAR
A	0.044430	128	80
A			
A	0.039403	180	78
A			
A	0.038414	166	77
A			
A	0.037133	141	81
B	0.023154	178	76

Table 6-10. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Mulch) in Arcsine Transformed Coverage Estimates for Planted Shrubs Between 1976, 1977, 1978, 1980, and 1981 on Plot R-1, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=745 MS=.0010338

GROUPING	MEAN	N	MULCH
A	0.048192	190	1
A			
A	0.041971	208	2
B	0.027079	187	4
B			
B	0.026747	208	3

[1/] Mulch treatment regimes are illustrated on Figure 6-1.

Table 6-11. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Block) in Arcsine Transformed Coverage Estimates for Invaded Shrubs between 1976, 1977, 1978, 1980, and 1981 on Plot R-1, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=5 MS=2.9E-04

GROUPING	MEAN	N	BLOCK
A	0.046826	18	1
A			
B A	0.034393	16	2
B			
B	0.022226	9	3

[1/] Block configuration is illustrated on Figure 6-1.

Table 6-12. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Fertilizer) in Arcsine Transformed Coverage Estimates for Invaded Shrub Species Between 1976, 1977, 1978, 1980, and 1981 on Plot R-1, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=5 MS=2.9E-04

GROUPING	MEAN	N	FERTILIZ
A	0.069125	9	2
B	0.031896	11	3
B			
B	0.028012	10	4
B			
B	0.026160	13	1

[1/] Fertilizer treatment regimes are illustrated on Figure 6-1.

Table 6-13. Summary of Biomass (kg/ha) of Planted and Invaded Grasses and Forbs During 1981 for Experimental Revegetation Plot R-1, Tract C-a

Treatment Combination	Grasses		Forbs		Total Biomass
	Planted	Invaded	Planted	Invaded	
No Mulch No Fertilizer	795.9	2.0	172.3	25.1	995.3
No Mulch Fertilized at Sowing	458.1	27.1	125.8	46.5	657.5
No Mulch Fertilized First Season	630.9	48.4	104.8	28.2	812.3
No Mulch Fertilized Sowing/First	703.3	27.4	88.9	17.4	837.0
Hydromulch No Fertilizer	378.3	126.3	270.3	23.8	798.7
Hydromulch Fertilized at Sowing	468.9	6.1	199.0	37.7	711.7
Hydromulch Fertilized First Season	747.3	70.8	77.0	30.4	925.5
Hydromulch Fertilized Sowing/First	571.8	41.2	233.2	75.8	922.0
Straw Crimped No Fertilizer	572.8	12.1	168.3	63.4	816.6
Straw Crimped Fertilized at Sowing	464.4	6.8	220.5	49.6	741.3
Straw Crimped Fertilized First Season	361.5	43.7	201.3	80.2	686.7
Straw Crimped Fertilized Sowing/First	574.3	55.5	88.8	40.5	759.1
Straw with Netting No Fertilizer	818.0	34.8	18.4	9.8	881.0
Straw with Netting Fertilized at Sowing	591.9	24.2	215.7	98.7	930.5
Straw with Netting Fertilized First Season	675.9	11.3	134.6	10.9	832.7
Straw with Netting Fertilized Sowing/First	772.7	45.9	117.9	51.8	988.3
Average	599.1	36.5	152.3	43.1	831.0

undisturbed sagebrush community surrounding the plots. Data from the baseline studies indicate that production of grasses and forbs was 304 kg/ha (RBOSC 1977b), while grass and forb production recorded during 1981 on Plot R-1 was 435.3 kg/ha (see Section 3.1D). Based on these data, revegetation efforts on Plot R-1 have resulted in production values in excess of those for existing plant communities of the area.

As shown in Table 6-13, planted grasses averaged 599.1 kg/ha for the 16 different treatment combinations. This biomass accounts for 72.1 percent of the total biomass averaged over all 16 treatment combinations, which is higher than the 39.5 percent noted for 1978 (the only other year that biomass determinations were made). Plots on which straw was crimped and fertilizer added at the beginning of the first full growing season had the lowest biomass (361.5 kg/ha). The highest biomass, 818.0 kg/ha, was encountered on those plots that received straw mulch covered with netting and no fertilizer. As would be expected, the grass species that accounted for most of the planted grass coverage (wheatgrass species and, to a lesser extent, green needlegrass) also constituted most of the planted grass biomass. Invading grasses were responsible for 4.4 percent of the total biomass averaged over all 16 treatment combinations, with an average of 36.5 kg/ha (Table 6-13). Plots with no mulch and no fertilizer had the lowest biomass for invaded grasses (2.0 kg/ha), while those plots that were hydromulched and not fertilized exhibited the highest biomass for invaded grasses (126.3 kg/ha). Cheatgrass, squirreltail, and crested wheatgrass (Agropyron cristatum) accounted for most of the invaded grass biomass.

Comparing the 1981 grass biomass data for all treatment combinations, no significant differences for planted grasses were found; however, significant differences for almost all of the categories for invaded grasses were evident (Table 6-14). Invaded grass biomass is significantly greater with Mulch Treatment 2 (hydromulch) than on the other three treatment combinations (Table 6-15). It is unclear why hydromulch is associated with greater invading grass biomass since there was no corresponding significant difference for the mulch main effect for invaded grass coverage (Table 6-2). Fertilizer Treatment 1 (no fertilizer) produced significantly greater invaded grass biomass than the other three fertilizer treatments (Table 6-15). As is the

Table 6-14. Results of Three-way ANOVA's For Grass and Forb Biomass of Planted and Invaded Species for Treatment Combinations During 1981 on Experimental Revegetation Plot R-1, Tract C-a [1/]

Growth Form	Source of Variation													
	Block		Mulch		Fertilizer		Block x Mulch		Block x Fertilizer		Mulch x Fertilizer		Block x Mulch x Fertilizer	
	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]
Grasses Planted	0.05	0.9491	0.49	0.6932	0.52	0.6723	0.40	0.8782	0.33	0.9194	0.45	0.9043	0.33	0.9959
Grasses Invaded	2.38	0.1013	4.42**	0.0073	7.99**	0.0002	5.89**	0.0001	9.84**	0.0001	23.25**	0.0001	12.71**	0.0001
Forbs Planted	0.18	0.8385	0.92	0.4378	1.06	0.3718	0.51	0.8010	0.27	0.9484	1.59	0.1268	1.05	0.4142
Forbs Invaded	5.35**	0.0053	1.03	0.3792	0.73	0.5412	0.66	0.6820	1.12	0.3527	1.37	0.1989	0.69	0.8215

** Significant at $\alpha = 0.025$

1/ Complete analyses are presented in Appendix 6-1.2.

2/ Represents the significance probability (α) associated with F.

Table 6-15. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Mulch and Fertilizer) in Biomass of Invaded Grasses for 1981 on Plot R-1, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=59 MS=43.6091

GROUPING	MEAN	N	MULCH
A	10.855556	27	2
B	6.340909	22	4
B			
B	5.245833	24	1
B			
B	4.882759	29	3

ALPHA LEVEL=.05 DF=59 MS=43.6091

GROUPING	MEAN	N	FERTILIZ
A	14.013333	15	1
B	6.531250	32	3
B			
B	6.000000	34	4
B			
B	3.661905	21	2

[1/] Mulch and fertilizer treatment regimes are illustrated on Figure 6-1.

case with mulch, there was no corresponding significant main effect difference related to fertilizer application for invaded grass coverage (Table 6-2).

The one-way ANOVA comparing biomass between 1978 and 1981 indicated significant differences for both planted and invaded grass species (Table 6-16). The biomass of planted and invaded grasses increased significantly in 1981 in comparison to 1978 (Table 6-17). This may be attributed to two factors: years of growth and moisture. Since 1981 was the sixth growing season, it is not surprising that biomass was greater than after the third growing season (1978). Considering the precipitation patterns during the April to October growing season, rainfall has increased since 1978 (Table 6-18).

Using the three-way ANOVA to compare grass biomass for 1978 and 1981, the origin of the differences mentioned above is unclear, as there are no significant differences for planted grasses (Table 6-19). The differences for invaded grass biomass are due to all of the main and interaction effects noted in Table 6-19. Block 3 is significantly greater in biomass than either Blocks 1 or 2; Mulch Treatment 2 (hydromulch) produced significantly more biomass than the other three mulch treatments; and Fertilizer Treatment 1 (no fertilizer) produced significantly more biomass than the other fertilizer treatments (Table 6-20).

Planted forb biomass accounted for 18.3 percent of the total biomass for R-1, which is much lower than the 44.8 percent of total biomass recorded in 1978 (RBOSC 1979). Planted forb biomass averaged 152.3 kg/ha and ranged from 18.4 to 270.3 kg/ha (Table 6-13). The lowest biomass was encountered on plots mulched with straw, covered with netting, and lacking fertilizer; these plots also had the highest planted grass biomass. Plots that were hydromulched and not fertilized had the highest planted forb biomass. As expected, plots with the highest planted forb coverage also were the plots with the highest biomass. Invaded forbs averaged 43.1 kg/ha biomass over all 16 treatment combinations and ranged from 9.8 to 98.7 kg/ha (Table 6-13). Invaded forbs accounted for 5.2 percent of the total R-1 biomass. Plots that were mulched with straw, covered with netting, and not fertilized exhibited the lowest invaded forb biomass, whereas biomass was the highest on those plots that were straw

Table 6-16. Results of One-way ANOVA Comparing Aboveground Biomass Measurements for Grasses and Forbs Between 1978 and 1981 on Experimental Revegetation Plot R-1, Tract C-a[1/]

Growth Form	Source of Variation Year	
	F	PR>F [2/]
Grasses Planted	91.54**	0.0001
Grasses Invaded	4.38*	0.0389
Forbs Planted	51.89**	0.0001
Forbs Invaded	87.08**	0.0001

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 6-1.2.

[2/] Represents the significance probability (α) associated with F.

Table 6-17. Results of Duncan's Multiple Range Tests for Significant Differences in Biomass of Planted (first listing) and Invaded (second listing) Grass Species Between 1978 and 1981 on Plot R-1, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=360 MS=3103.54

GROUPING	MEAN	N	YEAR
A	60.789418	189	81
B	4.705780	173	78

ALPHA LEVEL=.05 DF=98 MS=243.077

GROUPING	MEAN	N	YEAR
A	7.509859	71	81
B	0.317241	29	78

Table 6-18. Average Rainfall[1/] (inches) Recorded at Experimental Revegetation Plot R-1 from 1976 to 1981, Tract C-a

Month	Year						Mean
	1976	1977	1978	1979	1980	1981	
April	ND	0.31	0.64	0.48[4/]	1.01	0.36[4/]	0.56
May	ND	0.60	1.41	2.71[4/]	1.65	0.95	1.46
June	1.41	0.24	1.11	0.48[4/]	0.03	1.43	0.78
July	0.43	1.29	0.28	0.81	1.01	2.28	1.02
August	1.30	2.13	0.67	0.94	2.48	1.27	1.47
September	ND	1.05[2/]	0.52	0.43	0.62	1.26	0.78
October	ND	1.23[2/]	0.20	0.84	0.97	1.83	1.01
November	0.91	2.70[3/]	ND	ND	ND	ND	1.81
Total	4.05	9.55	4.83	6.69	7.77	9.38	8.89

1/ Rainfall has been averaged between the upper and lower gauges unless otherwise noted).

2/ Data from October 1 to November 15.

3/ Data from November 16 to December 10.

4/ Data from wedge gauge at Meteorological Site 2.

Table 6-19. Results of Three-way ANOVA's For Grass and Forb Biomass of Planted and Invaded Species for Treatment Combinations During 1978 and 1981 in Experimental Revegetation Plot R-1, Tract C-a [1/]

Growth Form	Source of Variation													
	Block		Mulch		Fertilizer		Block x Mulch		Block x Fertilizer		Mulch x Fertilizer		Block x Mulch x Fertilizer	
	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]
Grasses Planted	0.01	0.9886	0.47	0.7106	0.38	0.7720	0.32	0.9246	0.23	0.9677	0.28	0.9800	0.27	0.9990
Grasses Invaded	7.02**	0.0018	7.42**	0.0003	10.82**	0.0001	6.84**	0.0001	16.25**	0.0001	22.03**	0.0001	18.07**	0.0001
Forbs Planted	0.07	0.9347	0.47	0.7072	0.66	0.5808	0.43	0.8568	0.17	0.9835	1.12	0.3472	0.51	0.9509
Forbs Invaded	3.23*	0.0409	0.17	0.9114	1.19	0.3139	0.54	0.7753	1.25	0.2799	1.28	0.2449	0.59	0.9086

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 6-1.2.

[2/] Represents the significance probability (α) associated with F.

Table 6-20. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Block, Mulch, and Fertilizer) in Biomass of Invaded Grasses for 1978 and 1981 on Plot R-1, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=60 MS=38.5089

GROUPING	MEAN	N	BLOCK
A	9.500000	24	3
B	4.579487	39	1
B			
B	3.670270	37	2

ALPHA LEVEL=.05 DF=60 MS=38.5089

GROUPING	MEAN	N	MULCH
A	10.465385	26	2
B	4.438462	26	4
B			
B	3.247826	23	1
B			
B	3.208000	25	3

ALPHA LEVEL=.05 DF=60 MS=38.5089

GROUPING	MEAN	N	FERTILIZ
A	13.753333	15	1
B	5.153333	30	3
B			
B	4.088235	34	4
B			
B	2.023810	21	2

[1/] Block configuration, and mulch and fertilizer treatment combinations are illustrated on Figure 6-1.

mulched, covered with netting, and fertilized at the time of planting. Scarlet gilia, Douglas chaenactis, and goldenweed were the most prevalent invaded forbs in terms of coverage as well as biomass.

The three-way ANOVA comparing 1981 forb biomass between the different treatments indicates no significant differences for planted forbs but a significant block main effect difference for the invaded forbs (Table 6-14). It is unclear why Block 3 is significantly greater than Blocks 1 or 2 (Table 6-21).

The one-way ANOVA comparing forb coverage between 1978 and 1981 exhibited significant differences for both planted and invaded forbs (Table 6-16). As expected, planted forb biomass was significantly greater in 1981 than in 1978 (Table 6-22). The significantly lower biomass for invaded forbs in 1981 indicates that these species are being outcompeted by the planted native species. The statistical comparison (three-way ANOVA) of biomass between years indicates no significant differences for the planted forbs (Table 6-19). However, significant differences among blocks (main effects) were evident for the invaded forbs (Table 6-19). It is unclear why Block 3 is significantly greater in invaded forb species biomass than the other two blocks (Table 6-23).

3. R-1 Soil Chemistry - Soil samples (at depths of 0 cm, 1-25 cm, and 26-50 cm) were collected on October 8, 1981 from each of the four no-mulch treatment combinations from the three blocks. A total of 12 soil samples for each soil depth was mixed to form three composite samples for each soil depth. Because 1981 was the only year that soil samples have been taken on R-1, these data are not amenable to statistical analyses.

Physical and chemical analyses included determinations for texture, pH, cation exchange capacity, conductivity, sodium, lime, organic matter, organic nitrogen, NO_3, P, K, Ca, Mg, S, B, Zn, Fe, Mn, and Cu. Data from each block and the average of the three blocks are presented on Table 6-24. Based on the average values, the R-1 soil is a sandy loam that is slightly alkaline. If amendments are continued, fertilizer recommendations would include approximately 7 kg/ha nitrogen, 45 kg/ha P_2O_5, and 46 kg/ha K_2O.

Table 6-21. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Block) in Biomass of Invaded Forbs on Plot R-1, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=259 MS=26.5602

GROUPING	MEAN	N	BLOCK
A	3.954545	110	3
B	2.227619	105	1
B			
B	1.725000	92	2

[1/] Block configuration is illustrated in Figure 6-1.

Table 6-22. Results of Duncan's Multiple Range Tests for Significant Differences in Biomass of Planted (first listing) and Invaded (second listing) Forbs Species Between 1978 and 1981 on Plot R-1, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=248 MS=312.95

GROUPING	MEAN	N	YEAR
A	17.867683	164	81
B	0.902326	86	78

ALPHA LEVEL=.05 DF=387 MS=58.6535

GROUPING	MEAN	N	YEAR
A	11.792208	77	78
B	2.698077	312	81

Table 6-23. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Block) in Biomass of Invaded Forbs Between 1978 and 1981 on Plot R-1, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=341 MS=72.3361

GROUPING	MEAN	N	BLOCK
A	5.974638	138	3
B	3.736296	135	1
B			
B	3.628448	116	2

[1/] Block configuration is illustrated on Figure 6-1.

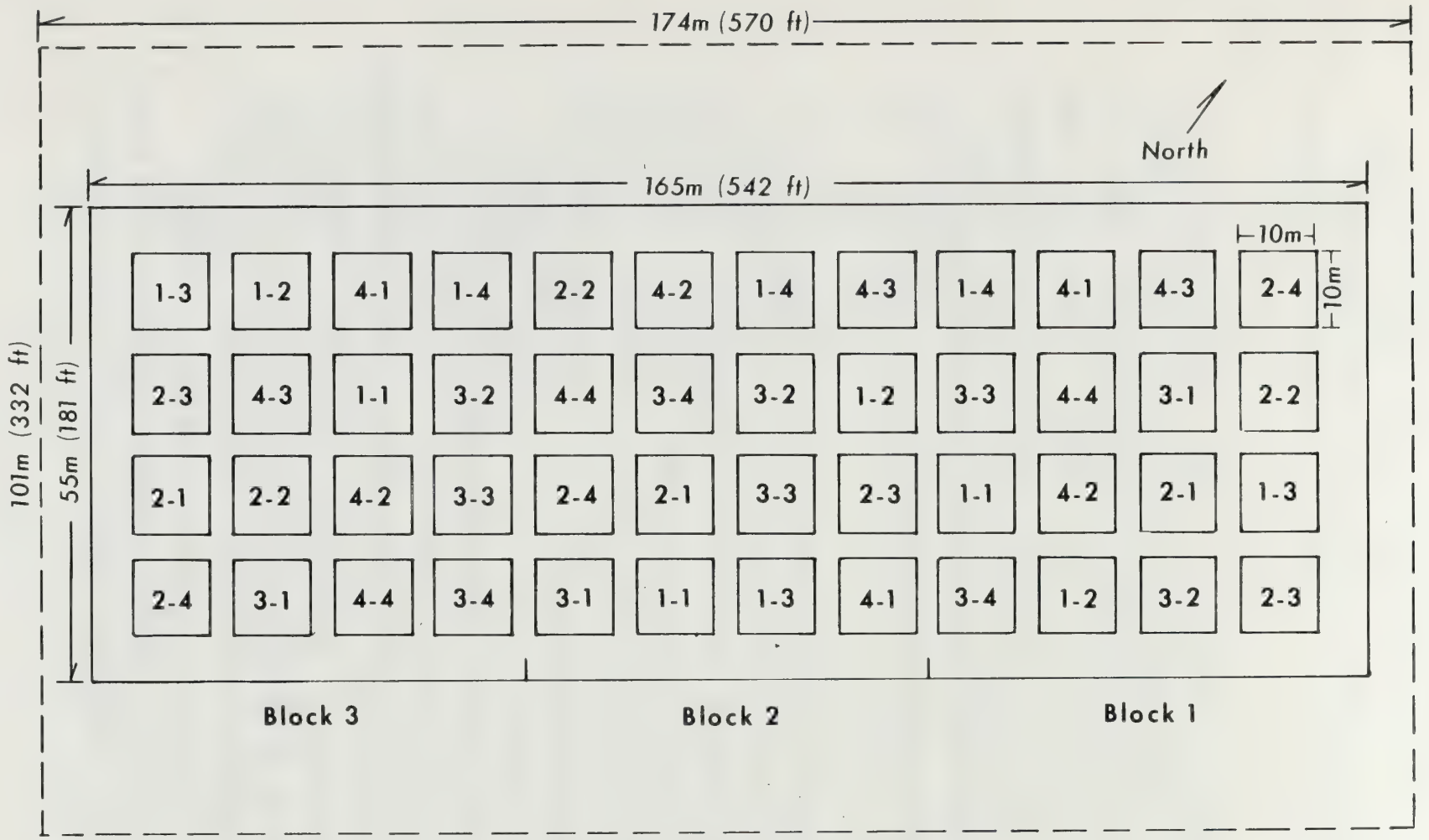
Table 6-24. Physical and Chemical Soil Constituents for Blocks 1, 2, and 3 of Experimental Revegetation Plot R-1 for 1981, Tract C-a

Block	Soil Depth	Texture	pH	Cation Exchange Capacity (meq /100g)	Salt (mmhos /100g)	Na (meq /100g)	Lime (%)	Organic Matter (%)	Organic Nitrogen (lbs)	NO_3 (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
1	0	Sandy Clay Loam	8.1	19.9	0.5	0.3	2.9	2.3	69.0	21	8	110	3000	190	7	1.0	0.3	3.1	2.0	0.6
	1-25	Sandy Clay Loam	8.3	17.5	0.5	0.3	4.7	1.8	54.0	15	2	40	3100	210	4	1.0	0.3	2.8	1.2	0.5
	26-50	Sandy Loam	8.4	10.8	0.8	0.7	7.7	1.4	49.0	18	2	30	3000	320	5	1.0	0.3	5.2	1.8	0.6
2	0	Sandy Loam	8.2	14.3	0.9	0.3	3.6	3.3	60.0	17	22	190	3600	220	14	0.9	0.2	2.8	1.8	0.6
	1-25	Sandy Loam	8.2	12.5	0.8	0.3	4.5	2.4	60.0	14	3	60	2400	230	5	0.6	0.4	2.8	1.4	0.5
	26-50	Sandy Loam	8.6	11.8	0.8	1.0	7.1	1.7	59.5	19	2	40	3300	330	3	1.3	0.3	3.5	1.4	0.5
3	0	Sandy Loam	8.2	13.0	0.8	0.2	4.6	2.2	60.0	17	9	210	3200	210	8	1.1	0.2	2.3	2.0	0.5
	1-25	Sandy Loam	8.3	12.2	0.8	0.5	5.5	2.1	60.0	14	2	60	3600	280	3	1.5	0.2	2.3	1.3	0.4
	26-50	Sandy Loam	8.5	12.0	1.0	1.0	5.0	1.6	56.0	22	3	50	2700	300	10	0.9	0.4	3.0	1.5	0.5
Average	0	Sandy Loam	8.2	15.7	0.7	0.3	3.7	2.6	63.0	18	13	170	3267	207	10	1.0	0.2	2.7	1.9	0.6
	1-25	Sandy Loam	8.3	14.1	0.7	0.4	4.9	2.1	58.0	14	2	53	3033	240	4	1.0	0.3	2.6	1.3	0.5
	25-26	Sandy Loam	8.5	11.5	0.9	0.9	6.6	1.6	54.8	20	2	40	3000	317	6	1.0	0.3	3.9	1.6	0.5

b. Experimental Revegetation Plot R-2 Cover estimates and the clipping of grass and forb species for biomass determinations on Plot R-2 took place from July 29 to August 10, 1981. These data are presented in their entirety in Appendix 6-1.3. The Plot R-2 configuration is illustrated in Figure 6-2.

1. R-2 Cover - Coverage for all grass, forb, and shrub species over the different treatment combinations ranged from 25.2 to 36.7 percent, with a mean of 30.1 percent (Table 6-25). This average cover is lower than the 37.1 percent recorded during 1980 (RBOSC 1981a). The lowest total cover was encountered on those plots that were not mulched but were fertilized at the time of sowing as well as at the beginning of the first full growing season. Plots that were hydromulched and fertilized at the beginning of the first full growing season yielded the highest values for total cover -- 36.7 percent.

Planted grasses accounted for 39.5 percent of the total coverage, which is comparable to the 41 percent for 1980; mean coverage was 11.9 percent and ranged from 8.7 to 15.6 percent (Table 6-25). Plots that were straw mulched, covered with netting, and fertilized at the start of the first full growing season exhibited the lowest planted grass coverage. Conversely, plots that were not mulched but were fertilized at the time of planting and again at the beginning of the first full growing season had the highest planted grass coverage. Wheatgrass species and Indian ricegrass (Oryzopsis hymenoides) were the dominant planted grasses, while green needlegrass was a common subordinate species. Invaded grasses accounted for 4.0 percent of the total coverage, while the mean value for invaded grasses over all treatment combinations was 1.2 percent (Table 6-25). The lowest invaded grass coverage (0.3 percent) was encountered on plots that were not mulched but were fertilized at the time of sowing and at the beginning of the first full growing season. Plots that were straw mulched, covered by netting, and fertilized at the start of the first full growing season exhibited the highest coverage (3.8 percent; Table 6-25). Needle-and-thread (Stipa comata) and, to a lesser extent, crested wheatgrass (Agropyron cristatum) were the dominant invaded grass species.



Seeding Rate 18 kg/ha (16 lb/acre)

Mulch Treatments: (Applied at Sowing: First Numeral in Treatment Designation)
1 = No Mulch
2 = Hydromulch
3 = Straw Mulch Followed by Crimping
4 = Straw Mulch With Netting

Fertilizer Treatments: (180 kg/ha, 10-5-5) (Second Numeral in Treatment Designation)
1 = No Fertilizer
2 = Fertilizer at Time of Sowing
3 = Fertilizer at Beginning of First Full Growing Season
4 = Fertilizer at Sowing & Beginning of First Full Growing Season

Figure 6-2. Treatment Configuration for Experimental Revegetation Plot R2, Tract C-a.

Table 6-25. Coverage (%) of Planted and Invaded Grasses, Forbs, and Shrubs for Experimental Revegetation Plot R-2 during 1981, Tract C-a

Treatment Combination	Grasses		Forbs		Shrubs		Total Cover
	Planted	Invaded	Planted	Invaded	Planted	Invaded	
No Mulch No Fertilizer	9.1	0.9	10.3	3.8	7.0	0.2	31.3
No Mulch Fertilized at Sowing	12.8	1.1	5.2	3.4	6.5	0.7	29.7
No Mulch Fertilized First Season	11.3	0.8	7.5	4.6	8.0	0.3	32.5
No Mulch Fertilized Sowing/First	15.6	0.3	2.8	2.9	3.6	ND	25.2
Hydromulch No Fertilizer	9.7	0.8	4.8	3.6	10.9	0.2	30.0
Hydromulch Fertilized at Sowing	10.4	0.5	6.4	3.8	6.6	ND	27.7
Hydromulch Fertilized First Season	12.1	0.7	9.3	4.3	9.9	0.4	36.7
Hydromulch Fertilized Sowing/First	13.3	1.7	5.8	3.3	8.2	0.6	32.9
Straw Crimped No Fertilizer	13.8	1.2	8.5	3.3	4.0	0.5	31.3
Straw Crimped Fertilized at Sowing	12.4	1.4	10.3	4.9	2.1	1.3	32.4
Straw Crimped Fertilized First Season	14.2	1.2	5.8	3.0	6.3	0.8	31.3
Straw Crimped Fertilized Sowing/First	12.4	0.5	9.8	3.7	2.4	0.8	29.6
Straw with Netting No Fertilizer	10.1	1.5	6.8	4.5	4.4	0.1	27.4
Straw with Netting Fertilizer at Sowing	13.7	0.8	9.3	1.5	2.3	1.1	28.7
Straw with Netting Fertilized First Season	8.7	3.8	7.9	3.0	4.0	0.1	27.5
Straw With Netting Fertilized Sowing/First	10.3	1.9	6.8	4.3	3.3	0.2	26.8
Average	11.9	1.2	7.3	3.6	5.6	0.5	30.1

A statistical comparison of 1981 cover data between the 16 treatment combinations exhibited no significant differences for planted grasses and only one significant interaction effect (mulch x fertilizer) for invaded grasses (Table 6-26).

Significant differences were exhibited for planted and invaded grasses when the coverage data between years are compared by a one-way ANOVA (Table 6-27). Planted grass coverage is significantly higher in 1980 than in 1981, both of which are significantly greater than in any of the other three sampling years (Table 6-28). This higher 1980 coverage may be due to the greater rainfall during the first few months of the 1980 growing season, as compared to the precipitation received during the same months of 1981 (Table 6-29). The increased rainfall early in 1980 may have allowed for more robust growth early in the season, resulting in greater planted grass coverage in 1980 than in 1981. Invaded grass coverage was significantly higher in 1976 than in any other sampling year (Table 6-28). This was probably due to the presence of large amounts of bare ground and the weak competition from the newly seeded grass species, factors that favor the growth of invaded species. Through time, however, the planted grasses became more competitive, resulting in lower invaded grass coverage (Table 6-28).

Utilizing a three-way ANOVA to compare grass coverage over five years, it appears that the differences mentioned above are due to significant main effect differences in blocks for the planted grasses, and mulch treatments for the invaded grasses (Table 6-30). It is unclear why Blocks 3 and 2 have significantly higher planted grass coverage than Block 1 (Table 6-31). Invaded grass coverage was significantly higher on Mulch Treatments 4 (straw mulch covered by netting) and 3 (crimped straw mulch) than on the other two mulch treatments. The straw mulch probably contained some unwanted grass seeds that were responsible for the high invaded grass coverage on these mulched plots.

Planted forb coverage accounted for 24.3 percent of the total plant coverage (as compared to 22 percent in 1980) over all treatment combinations. Planted forb coverage ranged from 2.8 to 10.3 percent and averaged 7.3 percent (Table 6-25). Plots that had no mulch and were fertilized at the time of

Table 6-26. Results of Three-Way ANOVA's For Grass, Forb, and Shrub Coverage of Planted and Invaded Species Among Treatment Combinations During 1981 on Experimental Revegetation Plot R-2, Tract C-a[1/]

Growth Form	Source of Variation: Block F	Block PR>F [2/]	Mulch F	Mulch PR>F [2/]	Fertilizer F	Fertilizer PR>F [2/]	Block x Mulch F	Block x Mulch PR>F [2/]	Block x Fertilizer F	Block x Fertilizer PR>F [2/]	Mulch x Fertilizer F	Mulch x Fertilizer PR>F [2/]	Block x Mulch x Fertilizer F	Block x Mulch x Fertilizer PR>F [2/]
Grasses Planted	2.98	0.0539	0.44	0.7305	0.35	0.7940	0.20	0.9776	0.45	0.8463	0.45	0.9028	0.40	0.9858
Grasses Invaded	3.05	0.0603	1.11	0.3568	0.66	0.5818	0.34	0.9131	0.41	0.8690	2.63**	0.0198	1.78	0.0835
Forbs Planted	0.62	0.5392	1.21	0.3122	0.35	0.7934	0.97	0.4514	1.00	0.4303	0.91	0.5231	1.60	0.0804
Forbs Invaded	1.59	0.2064	1.04	0.3779	0.16	0.9186	1.16	0.3304	0.52	0.7905	0.87	0.5512	0.59	0.9052
Shrubs Planted	0.28	0.7544	1.26	0.2955	0.21	0.8847	1.02	0.4234	0.42	0.8640	0.12	0.9986	0.27	0.9976
Shrubs Invaded [3/]														

** Significant at $\alpha = 0.025$

1/ Complete analyses are presented in Appendix 6-1.4.

2/ Represents the significance probability (α) associated with F.

3/ Invaded shrub species were not encountered in numbers sufficient to produce F values for the ANOVA.

Table 6-27. Results of One-way ANOVA Comparing Arcsine Transformed Coverage Estimates for Grasses, Forbs, and Shrubs Between 1976, 1977, 1978, 1980, and 1981 for Experimental Revegetation Plot R-2, Tract C-a[1/]

Growth Form	Source of Variation Year	
	F	PR>F [2/]
Grasses Planted	47.38**	0.0001
Grasses Invaded	20.79**	0.0001
Forbs Planted	60.36**	0.0001
Forbs Invaded	46.22**	0.0001
Shrubs Planted	22.64**	0.0001
Shrubs Invaded	3.72	0.0656

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 6-1.4.

[2/] Represents the significance probability (α) associated with F.

Table 6-28. Results of Duncan's Multiple Range Tests for Significant Differences in Arcsine Transformed Coverage Estimates for Planted (first listing) and Invaded (second listing) Grass Species Between 1976, 1977, 1978, 1980, and 1981 on Plot R-2, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=999 MS=.0082054

GROUPING	MEAN	N	YEAR
A	0.159301	184	80
B	0.114827	199	81
C	0.083881	188	78
C			
C	0.081300	214	77
D	0.040352	219	76

ALPHA LEVEL=.05 DF=168 MS=.0035028

GROUPING	MEAN	N	YEAR
A	0.126910	40	76
B	0.038416	31	80
B			
B	0.034230	60	81
B			
B	0.020650	31	78
B			
B	0.019093	11	77

Table 6-29. Average Rainfall[1/] (in.) Recorded at the Experimental Revegetation Plot R-2 from 1976 to 1981, Tract C-a

Month	Year 1976	1977	1978	1979	1980	1981	Mean
April	ND	0.35	0.63	0.48[4/]	1.07	0.36[4/]	0.58
May	ND	0.61	1.43	2.71[4/]	1.67	1.15	1.51
June	1.44	0.26	1.02	0.48[4/]	0.03	1.30	0.76
July	0.46	1.32	0.27	0.81[4/]	0.89	2.36	1.02
August	1.41	2.18	0.55	0.91	2.56	1.40	1.50
September	ND	0.99	0.58	0.40	0.67	1.28	0.78
October	ND	1.28[2/]	0.21	1.11	0.97	1.83	1.08
November	0.89	2.65[3/]	ND	ND	ND	ND	1.77
Total	4.20	9.64	4.69	6.90	7.86	9.68	9.00

[1/] Rainfall has been averaged between the upper and lower gauges (unless otherwise noted).

[2/] Data from October 1 to November 15.

[3/] Data from November 16 to December 10.

[4/] Data from wedge gauge at Meteorological Site 2.

Table 6-30. Results of Three-way ANOVA's For Grass, Forb, and Shrub Coverage of Planted and Invaded Species Among Treatment Combinations Between 1976, 1977, 1978, 1980, and 1981 for Experimental Revegetation Plot R-2, Tract C-a [1/]

Growth Form	Source of Variation													
	Block		Mulch		Fertilizer		Block x Mulch		Block x Fertilizer		Mulch x Fertilizer		Block x Mulch x Fertilizer	
	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]
Grasses Planted	4.10**	0.0169	1.60	0.1859	0.41	0.7501	0.64	0.6981	1.04	0.4002	0.92	0.5036	0.78	0.7295
Grasses Invaded	0.38	0.6844	7.68**	0.0001	0.55	0.6534	0.53	0.7824	0.50	0.8090	0.52	0.8567	0.37	0.9892
Forbs Planted	0.40	0.6688	0.68	0.5660	0.97	0.4078	1.89	0.0806	0.84	0.5393	1.32	0.2211	2.74**	0.0001
Forbs Invaded	2.49	0.0835	5.57**	0.0010	2.57	0.0520	0.92	0.4798	0.68	0.6641	1.22	0.2781	0.38	0.9911
Shrubs Planted	1.44	0.2389	11.73**	0.0001	0.43	0.7373	4.05**	0.0006	1.08	0.3705	0.42	0.9233	0.86	0.6254
Shrubs Invaded	2.02	0.4451	0.34	0.8168	0.69	0.6861	0.58	0.7390	0.23	0.9203	0.29	0.8895	...	...

** Significant at $\alpha = 0.025$

1/ Complete analyses are presented in Appendix 6-1.4.

2/ Represents the significant probability (α) associated with F.

... Invaded shrub species were not encountered in numbers sufficient to produce F values for the ANOVA.

Table 6-31. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences in Arcsine Transformed Coverage Estimates for Planted Grasses (Block) and Invaded Grasses (Mulch) Between 1976, 1977, 1978, 1980, and 1981 on Plot R-2, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=956 MS=.0097271

GROUPING	MEAN	N	BLOCK
A	0.101660	329	3
A			
A	0.098426	341	2
B	0.081310	334	1

ALPHA LEVEL=.05 DF=126 MS=.0052186

GROUPING	MEAN	N	MULCH
A	0.082671	52	4
A			
A	0.069508	38	3
B	0.028092	52	2
B			
B	0.024846	31	1

[1/] Block configuration and mulch treatment regimes are illustrated on Figure 6-2.

planting as well as at the beginning of the first growing season had the lowest planted forb coverage. The highest coverage was recorded on two different treatment regimes: plots with no mulch and no fertilizer, and plots that received crimped straw mulch and which were fertilized at sowing. The prominent planted forb species were Lewis flax and cicer milkvetch, with yellow sweetclover as a subordinant forb. Invaded forbs, primarily Cryptantha sericea, Douglas chaenactis, and the "unknown" forb category, accounted for 12.0 percent of the total plant coverage. Coverage ranged from 1.5 to 4.9 percent, and averaged 3.6 percent (Table 6-25). Plots that received crimped straw mulch and which were fertilized at sowing exhibited the highest invaded forb coverage, whereas the lowest coverage was found on those plots that received straw mulch with netting and fertilizer at the time of sowing.

The statistical comparison (three-way ANOVA) of 1981 forb coverage between the different treatment combinations indicated no significant differences for either main or interaction effects (Table 6-26). However, when the data were compared over the five years of sampling, significant differences for both the planted and invaded forbs were apparent (Table 6-27). Planted forb coverage was significantly higher in 1980 and 1981 than in 1977, 1978, or 1976. On the other hand, invaded forb coverage was significantly lower in 1980 and 1981 than for either 1977 or 1978 (Table 6-32). These variations among years appear to be the result of significant interaction (block x mulch x fertilizer) effect differences for the planted forbs and significant main effect (mulch) differences in the case of invaded forbs (Table 6-30). Invaded forb coverage was significantly lower on Mulch Treatment 2 (hydromulch) than on 4 or 1 (crimped straw with netting and no mulch treatments, respectively; Table 6-33).

Planted shrub coverage accounted for 18.6 percent of the total plant coverage of Plot R-2. This compares favorably to the nearly 17 percent measured in 1980 (RBOSC 1981a). The average planted shrub coverage was 5.6 percent. The lowest coverage (2.1 percent) was encountered on plots that were straw mulch crimped and fertilized at the time of sowing (Table 6-25). Plots that were hydromulched but not fertilized had the highest planted shrub coverage (10.9 percent; Table 6-25). The rabbitbrush species and winterfat were the dominant planted shrubs. Invaded shrub coverage averaged 0.5 percent, and ranged from

Table 6-32. Results of Duncan's Multiple Range Tests for Significant Differences in Arcsine Transformed Coverage Estimates for Planted (first listing) and Invaded (second listing) Forb Species Between 1976, 1977, 1978, 1980, and 1981 on Plot R-2, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=725 MS=.0052924

GROUPING	MEAN	N	YEAR
A	0.129842	124	80
A			
A	0.113896	125	81
B	0.037837	169	77
B			
B	0.036961	130	78
B			
B	0.029357	182	76

ALPHA LEVEL=.05 DF=845 MS=.0646805

GROUPING	MEAN	N	YEAR
A	0.354473	131	77
B	0.242664	107	78
C	0.090292	130	76
C			
D C	0.056058	235	80
D			
D	0.028321	247	81

Table 6-33. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Mulch) in Arcsine Transformed Coverage Estimates for Invaded Forbs for 1976, 1977, 1978, 1980, and 1981 on Plot R-2, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=802 MS=.0775596

GROUPING	MEAN	N	MULCH
A	0.179447	172	1
A			
B A	0.140754	218	4
B			
B C	0.114536	239	3
C			
C	0.069613	221	2

[1/] Mulch treatment regimes are illustrated on Figure 6-2.

0.1 to 1.3 percent; it accounted for 1.6 percent of the total coverage (Table 6-25). Only one invaded shrub, broom snakeweed, was encountered on the R-2 plots.

Based on 1981 shrub data, no significant main or interaction effects were noted (Table 6-26). However, when data from all five years were compared by a one-way ANOVA (Table 6-27), significant differences in coverage of planted shrubs were evident. Planted shrub coverage was significantly higher in 1980 and 1981 than in any of the previous years (Table 6-34), differences which may be attributed to mulch treatments (main effects) as well as a significant block x mulch interaction effect (Table 6-30). Plots given Mulch Treatment 2 (hydromulch) supported significantly greater planted shrub coverage than the other mulch treatments (Table 6-35). The interaction effect differences (block x mulch) may be attributed to mulch treatments rather than variations among blocks since only mulch had a significant main effect difference.

2. R-2 Biomass - The total biomass derived from the clipped grass and forb species averaged 492.1 kg/ha and ranged from 292.2 to 595.2 kg/ha (Table 6-36). The lowest biomass was encountered on plots that were hydromulched but not fertilized; plots that were straw mulched, covered by netting, and fertilized at the time of sowing exhibited the highest biomass. The total biomass for Plot R-2 (492.1 kg/ha) was lower than the grass and forb biomass for R-1 (831.0 kg/ha). This lower value for R-2 may be attributed to lower effective moisture on the south-facing slope of R-2 compared to that of R-1's north-facing slope. Nevertheless, the standing crops on both R-1 and R-2 exceed that for the sagebrush habitat type in the vicinity of Tract C-a (435.3 kg/ha in 1981 and 304 kg/ha during baseline studies).

In 1981, the biomass of planted grasses averaged 270.5 kg/ha and ranged from 145.9 to 376.6 kg/ha (Table 6-36). Planted grasses accounted for 55 percent of the total grass and forb biomass on Plot R-2, a value much higher than the 26.6 percent planted grass biomass encountered in 1978. Plots that were not mulched and were fertilized twice (at the time of planting and at the start of the first growing season) exhibited the highest biomass values, while the lowest biomass was encountered on the plots which were hydromulched but not fertilized. As expected, grass species with the highest cover values were also the species with the greatest biomass. Invaded grass species were

Table 6-34. Results of Duncan's Multiple Range Tests for Significant Differences in Arcsine Transformed Coverage Estimates for Planted Shrub Species Between 1976, 1977, 1978, 1980, and 1981 on Plot R-2, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=636 MS=.0082072

GROUPING	MEAN	N	YEAR
A	0.105924	114	80
A			
A	0.099371	110	81
B	0.065326	140	78
C	0.041257	119	77
D	0.017218	158	76

Table 6-35. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Mulch) in Arcsine Transformed Coverage Estimates for Planted Shrubs for 1976, 1977, 1978, 1980, and 1981 on Plot R-2 Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=593 MS=.0087377

GROUPING	MEAN	N	MULCH
A	0.095145	158	2
B	0.068983	152	1
C	0.043268	163	4
C			
C	0.042922	168	3

[1/] Mulch treatment regimes are illustrated on Figure 6-2.

Table 6-36. Summary of Biomass (kg/ha) of Planted and Invaded Grasses, and Forbs for Experimental Revegetation Plot R-2, Tract C-a

Treatment Combination	Grasses		Forbs		Total Biomass
	Planted	Invaded	Planted	Invaded	
No Mulch No Fertilizer	203.4	10.8	209.9	53.8	477.9
No Mulch Fertilized at Sowing	288.7	18.7	68.9	44.8	421.1
No Mulch Fertilized First Season	170.4	12.8	110.3	56.9	350.4
No Mulch Fertilized Sowing/First	376.6	7.1	38.8	101.9	524.4
Hydromulch No Fertilizer	145.9	14.0	90.5	41.8	292.2
Hydromulch Fertilized at Sowing	199.1	13.4	126.3	47.0	385.8
Hydromulch Fertilized First Season	244.1	8.8	184.8	43.3	481.0
Hydromulch Fertilized Sowing/First	286.7	29.3	103.5	45.0	464.5
Straw Crimped No Fertilizer	282.9	14.3	221.2	50.0	568.4
Straw Crimped Fertilized at Sowing	286.9	11.5	225.7	45.7	569.8
Straw Crimped Fertilized First Season	346.0	20.5	102.7	44.0	513.2
Straw Crimped Fertilized Sowing/First	314.7	5.6	192.3	57.4	570.0
Straw with Netting No Fertilizer	279.0	20.6	162.3	77.2	539.1
Straw with Netting Fertilized at Sowing	373.7	12.1	182.6	26.8	595.2
Straw with Netting Fertilized First Season	252.7	73.6	230.8	36.3	593.4
Straw with Netting Fertilized Sowing/First	276.4	31.8	150.6	68.1	526.9
Average	270.5	19.1	150.1	52.5	492.1

responsible for only 3.9 percent of the total biomass; they averaged 19.1 kg/ha for all the 16 treatment combinations (Table 6-36). Plots that received straw crimped mulch and fertilizer at the time of planting and again at the start of the first growing season exhibited the lowest biomass (5.6 kg/ha; Table 6-36). The highest invaded grass biomass (73.6 kg/ha) was encountered on plots that received straw mulch covered by netting and fertilizer at the beginning of the first full growing season. The invaded grasses making up most of this biomass were needle-and-thread and crested wheatgrass species.

The statistical comparison (three-way ANOVA) of 1981 grass biomass showed no significant differences for planted grasses. Significant block and mulch main effects as well as significant interaction effects (mulch x fertilizer and block x mulch x fertilizer) were noted for invaded grasses (Table 6-37). Block 1 exhibited significantly higher invaded grass biomass than Blocks 1 and 3 (Table 6-38). Mulch Treatments 3 (straw mulch followed by crimping) and 1 (no mulch) exhibited significantly lower biomass than the straw mulch with netting (Treatment 4; Table 6-38).

The one-way ANOVA comparing grass biomass between 1978 and 1981 exhibited significant differences for both planted and invaded grasses (Table 6-39). The Biomass of planted and invaded grass species was significantly greater in 1981 than in 1978 (Table 6-40). These results would be expected after six years of growth and with the increased precipitation noted from 1978 to 1981 (Table 6-29).

The three-way ANOVA to compare biomass between years did not indicate the source of planted grass biomass differences, since there are no significant main or interaction effect differences (Table 6-41). However, invaded grass species differences are a result of both main (block and mulch) and interaction (mulch x fertilizer and block x mulch x fertilizer) effect differences (Table 6-41). Biomass is significantly greater on Block 1 than on either Block 2 or 3, while Mulch Treatment 4 (straw mulch covered by netting) is significantly higher than the other three mulch treatments (Table 6-42). The interaction effect differences may be attributed to the mulch treatments in the case of mulch x fertilizer differences, and to both the block and mulch in the case of block x mulch x fertilizer differences.

Table 6-37. Results of Three-way ANOVA's For Grass and Forb Biomass of Planted and Invaded Species Among Treatment Combinations During 1981 on Experimental Revegetation Plot R-2, Tract C-a [1/]

Growth Form	Source of Variation													
	Block		Mulch		Fertilizer		Block x Mulch		Block x Fertilizer		Mulch x Fertilizer		Block x Mulch x Fertilizer	
	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]
Grasses Planted	0.54	0.5867	1.44	0.2329	0.43	0.7325	0.15	0.9893	0.25	0.9595	0.33	0.9648	0.35	0.9936
Grasses Invaded	3.36*	0.0466	2.94*	0.0469	2.32	0.0925	1.49	0.2104	2.00	0.0931	5.35**	0.0001	4.19**	0.0003
Forbs Planted	0.06	0.9419	2.41	0.0719	0.46	0.7124	1.08	0.3799	0.88	0.5148	0.92	0.5150	1.45	0.1348
Forbs Invaded	2.03	0.1339	1.28	0.2802	0.66	0.5813	0.79	0.5811	0.37	0.9000	0.42	0.9234	0.49	0.9607

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 6-1.4.

[2/] Represents the significance probability (α) associated with F.

Table 6-38. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Block and Mulch) in Biomass of Invaded Grasses for 1981 on Plot R-2, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=34 MS=18.0253

GROUPING	MEAN	N	BLOCK
A	6.108824	34	1
B	3.600000	27	2
B			
B	3.588235	17	3

ALPHA LEVEL=.05 DF=34 MS=18.0253

GROUPING	MEAN	N	MULCH
A	6.373077	26	4
A			
B A	5.246667	15	2
B			
B	3.461111	18	3
B			
B	3.115789	19	1

[1/] Block configuration and mulch treatment regimes are illustrated on Figure 6-2.

Table 6-39. Results of an One-way ANOVA Comparing Biomass Values for Grass and Forb Species for 1978 and 1981 on Experimental Revegetation Plot R-2, Tract C-a[1/]

Growth Form	Source of Variation: Year	
	F	PR>F [2/]
Grasses Planted	114.81**	0.0001
Grasses Invaded	14.85**	0.0002
Forbs Planted	73.91**	0.0001
Forbs Invaded	8.30**	0.0042

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 6-1.4.

[2/] PR>F represents the significance probability (α) associated with F.

Table 6-40. Results of Duncan's Multiple Range Tests for Significant Differences in Biomass of Planted (first listing) and Invaded (second listing) Grass Species for 1978 and 1981 on Plot R-2, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=380 MS=465.731

GROUPING	MEAN	N	YEAR
A	26.290863	197	81
B	2.617297	185	78

ALPHA LEVEL=.05 DF=87 MS=35.716

GROUPING	MEAN	N	YEAR
A	5.525000	60	81
B	0.317241	29	78

Table 6-41. Results of Three-way ANOVA's For Grass and Forb Biomass of Planted and Invaded Species Among Treatment Combinations Between 1978 and 1981 for Experimental Revegetation Plot R-2, Tract C-a [1/]

Growth Form	Source of Variation													
	Block		Mulch		Fertilizer		Block x Mulch		Block x Fertilizer		Mulch x Fertilizer		Block x Mulch x Fertilizer	
	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]
Grasses Planted	0.46	0.6304	0.81	0.4891	0.43	0.7319	0.19	0.9804	0.21	0.9747	0.23	0.9889	0.24	0.9995
Grasses Invaded	8.09**	0.0009	4.00**	0.0125	1.19	0.3239	1.89	0.1016	1.94	0.0924	6.47**	0.0001	6.95**	0.0001
Forbs Planted	0.01	0.9906	1.19	0.3147	0.23	0.8722	0.49	0.8190	0.45	0.8449	0.59	0.8025	0.98	0.4800
Forbs Invaded	1.12	0.3268	4.76**	0.0031	1.91	0.1260	0.61	0.7206	0.45	0.8461	0.62	0.7776	0.61	0.8941

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 6-1.4.

[2/] Represents the significance probability (α) associated with F.

Table 6-42. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Block and Mulch) for Biomass of Invaded Grasses for 1978 and 1981 on Plot R-2, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=50 MS=16.1291

GROUPING	MEAN	N	BLOCK
A	6.005882	34	1
B	2.495000	20	3
B			
B	2.474286	35	2

ALPHA LEVEL=.05 DF=50 MS=16.1291

GROUPING	MEAN	N	MULCH
A	6.431818	22	4
B	3.218519	27	2
B			
B	3.063158	19	3
B			
B	2.576190	21	1

[1/] Block configuration and mulch treatment regimes are illustrated on Figure 6-2.

The planted forb biomass averaged 150.1 kg/ha or 30.5 percent of the total herbaceous species biomass over all the treatment combinations, compared to the 1978 value of 44.7 percent. Plots which received no mulch and which were fertilized at the time of sowing and at the start of the first growing season exhibited the lowest biomass (38.8 kg/ha; Table 6-36). Plots with the highest planted forb biomass (230.8 kg/ha) were those that received straw covered by netting and fertilizer at the beginning of the first full growing season (Table 6-36). As might be anticipated, species with the highest forb coverage (Lewis flax, cicer milkvetch, and yellow sweetclover) also had the highest planted forb biomass. Invaded forbs accounted for 10.7 percent of the total at an average of 52.5 kg/ha (Table 6-36). The highest biomass (101.9 kg/ha) was found on the plots with the lowest planted forb biomass, whereas the lowest invaded forb biomass (36.3 kg/ha) was found on plots with the highest planted forb biomass (Table 6-36). Cryptantha sericea, Douglas chaenactis, and "unknown" forbs accounted for most of the invaded forb biomass.

There were no significant differences for forb biomass when the 1981 data were compared using a three-way ANOVA (Table 6-37). When data from 1978 and 1981 were compared, however, significant differences for both planted and invaded forbs were evident (Table 6-39). Planted forb biomass was significantly greater in 1981 than in 1978, whereas the converse was true for invaded forbs (Table 6-43).

Significant main or interaction effects occurred only for invaded forbs when data for 1978 and 1981 were compared using a three-way ANOVA (Table 6-41). Significant mulch main effect differences would account for the differences discussed above. Mulch Treatment 1 (no mulch) was responsible for significantly higher invaded forb coverage than the other three treatments (Table 6-44). The reason for this is unclear.

3. R-2 Soil Chemistry - Soil samples (at depths of 0 cm, 1-25 cm, and 26-50 cm) were collected on October 8, 1981 from each of the four no-mulch treatment combinations from the three blocks. A total of 12 soil samples for each depth was composited to produce three samples for each soil depth. Since 1981 was the first year that soil samples have been collected on R-2, these data are not amenable to statistical analyses.

Table 6-43. Results of Duncan's Multiple Range Tests for Significant Differences in Biomass of Planted (first listing) and Invaded (second listing) Forb Species for 1978 and 1981 on Plot R-2, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=239 MS=404.558

GROUPING	MEAN	N	YEAR
A	23.215323	124	81
B	0.929060	117	78

ALPHA LEVEL=.05 DF=339 MS=68.2625

GROUPING	MEAN	N	YEAR
A	6.977660	94	78
B	4.092308	247	81

Table 6-44. Results of Duncan's Multiple Range Tests for Significant Main Effect Differences (Mulch) for Biomass of Invaded Forbs for 1978 and 1981 on Plot R-2, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=293 MS=70.1091

GROUPING	MEAN	N	MULCH
A	8.205634	71	1
B	4.342222	90	4
B			
B	3.878824	85	2
B			
B	3.827368	95	3

[1/] Mulch treatment regimes are illustrated on Figure 6-2.

Physical and chemical analyses included determinations for texture, pH, cation exchange capacity, conductivity, sodium, lime, organic matter, organic nitrogen, NO_3, P, K, Ca, Mg, S, B, Zn, Fe, Mn, and Cu. Table 6-45 presents these data by block and the averages over the three blocks. Based on the by-block averages, the R-2 soil texture is a sandy loam that is slightly alkaline. If amendments are to be continued, fertilizer recommendations include 56 kg/ha of P_2O_5 and K_2O.

B. Experimental Revegetation on a Simulated Processed Shale Disposal Site

1. Objectives

During RBOSC's demonstration of surface retorting technology and subsequent commercial operations, processed shale will be produced as a by-product of surface retorting. This material will require surface disposal because not all of the processed shale can be returned as a slurry to in-situ retorts and/or returned to an open pit mine. RBOSC initiated revegetation experiments in 1976 to determine a feasible method of reestablishing a productive, self-sustaining livestock and/or wildlife habitat on processed shale disposal sites.

2. Methods

Revegetation Plot R-3 was established September 29 - November 8, 1976, and is located near the southeastern corner of Tract C-a (T2S, R99W, S10). The plot is situated in an area with a southeast-facing aspect and a slope of approximately 20 percent.

The plot was designed to simulate an artificial soil profile for use in overburden/processed shale disposal piles. This profile consists of 0.9 m of segregated sized overburden-like material, 0.3 m of subsoil, and 0.15 m of topsoil. The overburden-like material (0.9 m) is expected to inhibit the capillary migration of soluble, potentially toxic components from the processed shale into the surface plant growth medium. The plot configuration at Plot R-3 is designed to test the effectiveness of this reconstructed soil

Table 6-45. Physical and Chemical Soil Constituents for Blocks 1, 2, and 3 of Experimental Revegetation Plot R-2 for 1981, Tract C-a

Block	Soil Depth	Texture	pH	Cation Exchange Capacity (meq /100g)	Salt (mmhos /100g)	Na (meq /100g)	Lime (%)	Organic Matter (%)	Organic Nitrogen (lbs)	NO_3 (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	B (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
1	0	Sandy Loam	8.2	12.1	0.8	0.3	8.7	2.3	60.0	26	5	90	2900	110	8	1.3	0.1	3.7	2.0	0.4
	1-25	Sandy Loam	8.5	11.6	0.8	0.7	8.9	1.9	60.0	21	2	40	2600	160	11	1.0	0.4	3.8	1.4	0.5
	26-50	Sandy Loam	9.1	11.7	1.1	2.2	8.7	1.5	52.5	54	1	20	2200	230	14	1.0	0.3	5.3	1.6	0.3
2	0	Sandy Loam	8.2	12.2	0.9	0.3	7.8	2.3	60.0	31	5	70	2800	100	8	1.4	0.2	3.4	2.0	0.4
	1-25	Sandy Loam	8.6	11.9	0.9	0.9	9.2	1.7	59.5	26	2	30	2900	190	12	1.4	0.4	3.0	1.1	0.7
	26-50	Sandy Loam	9.4	10.1	1.4	4.1	8.7	0.7	24.5	108	1	20	2000	300	18	0.7	0.4	3.2	1.1	0.6
3	0	Sandy Loam	8.1	12.7	0.9	0.3	8.1	2.7	60.0	25	5	90	3400	110	8	1.3	0.2	3.0	1.5	0.6
	1-25	Sandy Loam	8.6	11.4	0.9	0.9	8.5	2.1	60.0	28	2	20	2800	150	10	1.3	0.4	3.4	1.2	0.4
	26-50	Sandy Loam	9.0	11.0	1.1	1.8	8.3	1.4	49.0	50	2	20	2600	210	14	1.0	0.5	3.9	1.3	0.6
Average	0	Sandy Loam	8.2	12.3	0.93	0.3	8.2	2.4	60.0	27	5	83	3033	107	8	1.3	0.2	3.4	1.8	0.5
	1-25	Sandy Loam	8.6	11.6	0.9	0.8	8.9	1.9	59.8	25	2	30	2767	167	11	1.2	0.4	3.4	1.2	0.5
	26-50	Sandy Loam	9.2	10.9	1.2	2.7	8.6	1.2	42.0	71	1	20	2267	247	15	0.9	0.4	4.1	1.3	0.5

profile, as well as various seeding rates and mulch regimes (Figure 6-3). Portions of Plot R-3 underlain by processed shale are considered treatments while those without processed shale serve as controls.

Soil samples were collected in 1981 from three depths (0 cm, 1-25 cm, and 26-50 cm) within holes centered above each of 36 plots on R-3. Soil samples were composited by depth for each row in both the treatment and control areas so that from the 108 individual samples collected, 36 samples were produced for chemical analysis.

Sampling was accomplished using a Soilmoisture Equipment Corp. soil sampling tube.

Additional information on experimental revegetation Plot R-3 is available in MDP Monitoring Report 5 (RBOSC 1980) and in Revegetation Annual Reports (RBOSC 1977, 1978, 1979).

3. Results and Discussion

a. Cover Data - Cover for grasses, forbs, and shrubs on Plot R-3 was estimated July 29 - August 10, 1981. These data are summarized on Table 6-46 and are presented in their entirety in Appendix 6-1.5.

Coverage during 1981 on control (not underlain by processed shale) portions of R-3 ranged from 33.9 to 44.1 percent for all species and averaged 38.4 percent. The highest coverage was recorded on the hay mulch/low seeding treatment combination, while the lowest coverage was found on the no mulch/low seeding and no mulch/high seeding treatments (Table 6-46). The mean coverage over all treatments has declined slightly from the 39.5 percent recorded during the 1980 growing season (RBOSC 1981a).

Mean coverage on the treatment (underlain by processed shale) portion of Plot R-3 during 1981 was 37.5 percent, with a range of 31.4 to 41.1 percent (Table 6-46). The no mulch/low seeding regime exhibited the lowest coverage, while the hay mulch/high seeding treatment had the highest coverage. These data

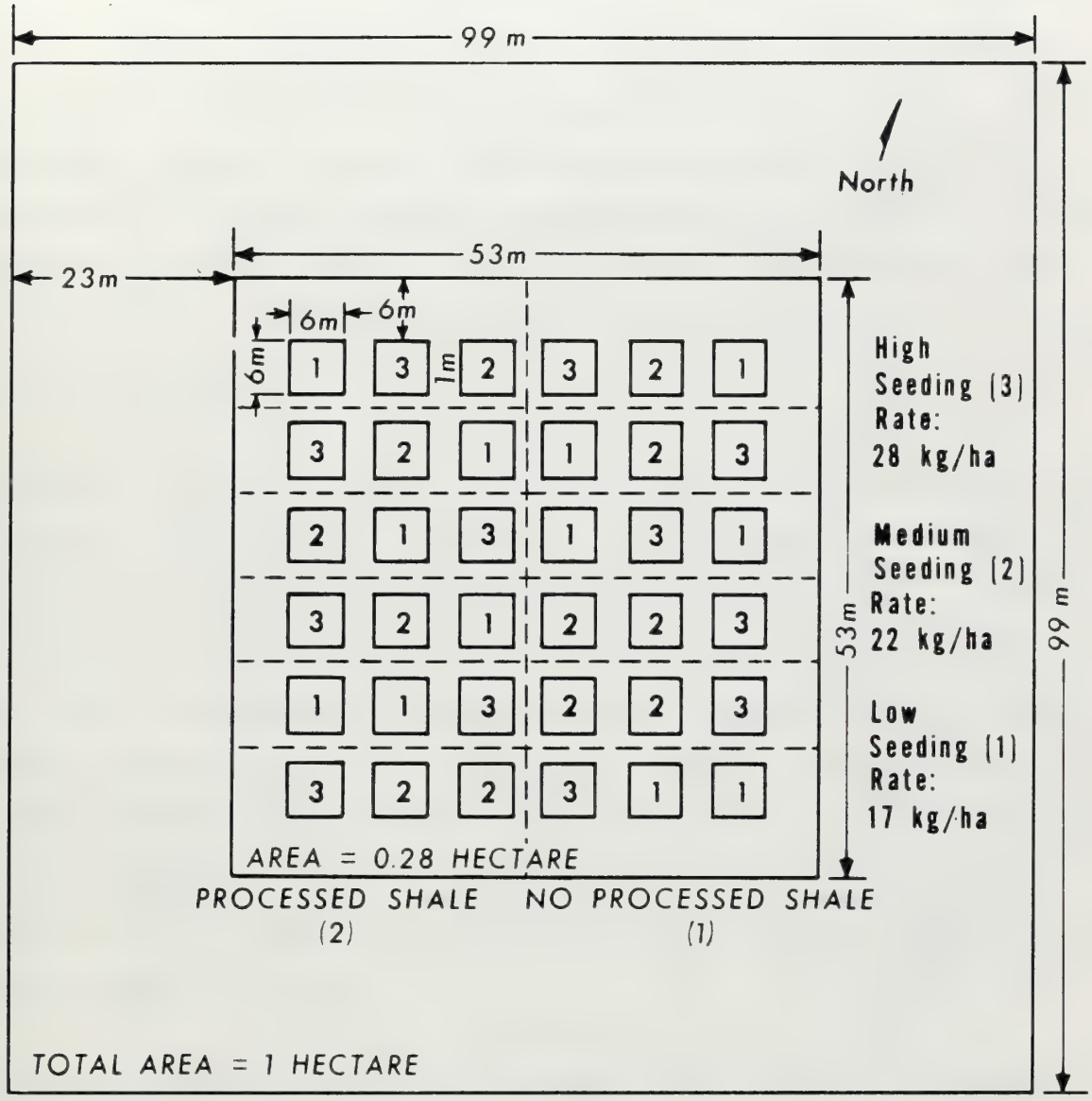


Figure 6-3. Configuration of Experimental Revegetation Plot over 'Tosco II' Processed Shale

Table 6-46. Coverage (%) of Planted and Invaded Grasses, Forbs, and Shrubs for Experimental Revegetation Plot R-3 (Tract C-a) During 1981[1/]

Mulch & Seeding Regimes[2/]	Control (No Processed Shale)							Treatment (Processed Shale)						
	Grasses		Forbs		Shrubs		Total Cover	Grasses		Forbs		Shrubs		Total Cover
	Planted	Invaded	Planted	Invaded	Planted	Invaded		Planted	Invaded	Planted	Invaded	Planted	Invaded	
No Mulch Low Seeding	19.3	3.7	7.0	0.3	3.3	0.3	33.9	18.2	6.7	3.5	1.0	2.0	...	31.4
No Mulch Medium Seeding	17.7	2.2	11.2	0.3	4.5	1.3	37.2	23.8	2.7	6.8	...	5.5	...	38.8
No Mulch High Seeding	26.0	0.7	3.2	...	4.0	...	33.9	28.5	0.2	2.3	...	5.5	...	36.5
Hydromulch Low Seeding	13.7	8.5	17.5	2.0	0.2	...	41.9	21.2	0.2	9.3	0.5	6.7	...	37.9
Hydromulch Medium Seeding	22.0	2.5	7.5	0.3	8.0	0.2	40.5	25.2	1.2	6.5	0.2	0.8	0.2	34.1
Hydromulch High Seeding	28.2	1.3	2.3	0.7	5.7	...	38.2	25.8	0.7	5.3	0.2	7.8	...	39.8
Hay Mulch Low Seeding	19.0	7.3	14.0	0.2	3.3	0.3	44.1	20.7	7.2	3.7	...	5.7	0.2	37.5
Hay Mulch Medium Seeding	24.0	2.2	8.3	0.2	3.7	...	38.4	21.2	6.0	8.3	...	3.8	1.5	40.8
Hay Mulch High Seeding	22.8	0.7	9.2	0.2	4.8	0.2	37.9	31.5	0.3	5.8	...	3.5	...	41.1
Range	13.7-28.2	0.7-8.5	2.3-17.5	0-2.0	0.2-8.0	0-1.3	33.9-44.1	18.2-31.5	0.2-7.2	2.3-9.3	0-1.0	0.8-7.8	0-1.5	31.4-41.1
Mean	21.4	3.2	8.9	0.5	4.2	0.3	38.4	24.0	2.8	5.7	0.2	4.6	0.2	37.5

1/ ... indicates no species present in this category.

2/ Mulch and seeding regimes are illustrated on Figure 6-3.

are similar to those reported for 1980 when coverage ranged from 25.7 to 43.8 percent, and the mean over all treatments was 33.9 percent (RBOSC 1981a).

Coverage of planted grasses during 1981 on the control plots ranged from 13.7 to 28.2 percent and averaged 21.4 percent. Coverage of planted grasses on the treatment plots was slightly higher than the control, averaging 24.0 percent and ranging from 18.2 to 31.5 percent (Table 6-46). As in previous years, wheatgrass (Agropyron) species and Indian ricegrass (Oryzopsis hymenoides) continue to be the most dominant planted grasses on both control and treatment portions of the site (Appendix 6-1.5). Cheatgrass (Bromus tectorum) and crested wheatgrass (Agropyron cristatum) continue to be the most prevalent invading grasses; however, respective coverage of invading grasses on control and treatment plots averaged only 3.2 and 2.8 percent.

A comparison of 1981 coverage data for all planted and invaded grasses using a three-way ANOVA indicates that significant differences exist only for the seeding main effect (Table 6-47). The results of Duncan's Multiple Range Tests on these significant differences are illustrated on Table 6-48. Coverage for planted grasses is significantly higher on plots seeded at 28 kg/ha than on those seeded at 17 kg/ha; however, neither of these seeding regimes produced significantly different coverage than that achieved with the 22 kg/ha seeding rate. Invading grasses exhibit significantly higher coverage on plots seeded at the lowest rate than plots treated with either the medium or high seeding rate. It is reasonable to assume that competition from planted species on those plots seeded at the higher rates is limiting the establishment of invaders.

Coverage of planted grass species is generally not dependent on substrate (shale versus no shale under the reconstructed soil profile) or on mulch treatments. However, analyses indicate that wheatgrass species and green needlegrass (Stipa viridula) are influenced by seeding rate (Table 6-49). A Duncan's Multiple Range Test suggests that most wheatgrass species exhibit significantly higher coverage on areas seeded at 28 kg/ha than plots seeded at the two lower rates (Table 6-50). Pubescent wheatgrass (Agropyron trichophorum), on the other hand, exhibited coverage which is significantly different for each of the seeding regimes (increased coverage with increased

Table 6-47. Results of a Three-way ANOVA Comparing Arcsine Transformed Coverage Estimates for Planted and Invaded Grass, Forb, and Shrub Species During 1981 on Experimental Revegetation Plot R-3, Tract C-a[1/]

Growth Form	Source of Variation: Substrate F	Substrate PR>F [2/]	Mulch F	Mulch PR>F [2/]	Seeding F	Seeding PR>F [2/]	Substrate x Mulch F	Substrate x Mulch PR>F [2/]	Substrate x Seeding F	Substrate x Seeding PR>F [2/]	Mulch x Seeding F	Mulch x Seeding PR>F [2/]	Substrate x Mulch x Seeding F	Substrate x Mulch x Seeding PR>F [2/]
Grasses Planted	1.69	0.1950	0.12	0.8837	3.72*	0.0265	0.27	0.7672	0.20	0.8216	0.04	0.9975	0.50	0.7341
Grasses Invaded	0.52	0.4749	0.41	0.6645	9.22**	0.0005	1.20	0.3116	0.30	0.7441	0.27	0.8982	1.23	0.3148
Forbs Planted	0.22	0.6381	1.30	0.2810	1.04	0.3596	0.05	0.9555	0.51	0.6011	0.85	0.4997	0.48	0.7519
Forbs Invaded[3/]	0.11	0.7470	0.14	0.8700	1.73	0.2089	1.74	0.2054	0.11	0.8966	0.46	0.6385		
Shrubs Planted	0.00	0.9721	0.30	0.7435	0.04	0.9565	0.72	0.4896	1.19	0.3139	0.08	0.9875	0.69	0.5993
Shrubs Invaded[3/]														

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Complete analyses are presented in Appendix 6-1.6.

2/ Represents the significance probability (α) associated with F.

3/ Missing values result from insufficient data to complete the ANOVA.

Table 6-48. Duncan's Multiple Range Test Results for Significant Differences in Arcsine Transformed Coverage Estimates During 1981 for Planted (first listing) and Invaded (second listing) Grasses Among Seeding Rates on Experimental Revegetation Plot R-3, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=152 MS=.0180488

GROUPING	MEAN	N	SEEDING
A	0.185516	54	3
A			
B A	0.137676	59	2
B			
B	0.118688	57	1

ALPHA LEVEL=.05 DF=40 MS=.0035739

GROUPING	MEAN	N	SEEDING
A	0.100939	20	1
B	0.040182	25	2
B			
B	0.017695	13	3

[1/] Seeding treatment regimes are illustrated on Figure 6-3.

Table 6-49. Results of a Three-way ANOVA Comparing Arcsine Transformed Coverage Estimates for Planted Species Encountered During 1981 on Experimental Revegetation Plot R-3, Tract C-a

Growth Form	Source of Variation: Substrate		Mulch		Seeding		Substrate x Mulch		Substrate x Seeding		Mulch x Seeding		Substrate x Mulch x Seeding	
	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]	F	PR>F[2/]
Grasses Planted														
Agropyron species	0.03	0.8639	0.31	0.7376	16.59**	0.0001	0.31	0.7359	0.57	0.5765	0.89	0.4899	1.35	0.2882
Agropyron trichophorum	25.28**	0.0001	0.15	0.8613	12.88**	0.0003	0.30	0.7448	1.76	0.2010	2.72	0.0622	2.62	0.0694
Bromus inermis	1.18	0.2916	1.21	0.3215	0.05	0.9532	0.92	0.4166	1.69	0.2144	2.89	0.0542	2.24	0.1081
Oryzopsis hymenoides	0.48	0.4969	0.67	0.5256	0.31	0.7347	2.66	0.0991	1.03	0.3788	1.86	0.1636	1.34	0.2950
Stipa viridula	0.15	0.7102	0.25	0.7850	5.72**	0.0198	2.41	0.1356	0.01	0.9874	4.87**	0.0166	4.49*	0.0375
Forbs Planted														
Astragalus cicer	4.71*	0.0437	2.70	0.0940	3.57*	0.0495	0.46	0.6396	4.54	0.0254	3.19	0.0380	0.99	0.4402
Linum lewisii[3/]	0.08	0.8211	2.58	0.4027	0.75	0.6324			0.00	0.9999				
Melilotus officinalis	0.33	0.5796	0.32	0.7358	0.71	0.5215	0.52	0.6143	1.52	0.2765	1.43	0.3082	0.27	0.8433
Shrubs Planted														
Atriplex canescens	0.29	0.6248	0.00	0.9983	1.27	0.3980	0.87	0.5023	0.38	0.7138	0.67	0.4738	3.03	0.1803
Chrysothamnus nauseosus[3/]														
Ceratoides lanata	0.38	0.5485	0.64	0.5476	0.82	0.4650	2.24	0.1528	1.31	0.3083	0.97	0.4599	2.45	0.1185
Purshia tridentata[3/]														

* Significant at $\alpha = 0.05$

** Significant at $\alpha = 0.025$

1/ Complete analyses are presented in Appendix 6-1.6.

2/ Represents the significance probability (α) associated with F.

3/ Missing values result from insufficient data to complete the ANOVA.

Table 6-50. Duncan's Multiple Range Test Results for Significant Differences in Arcsine Transformed Coverage Estimates Among Seeding Rates for Wheatgrass Species (first listing), Pubescent Wheatgrass (second listing), and Green Needlegrass (third listing) during 1981 on Plot R-3, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=19 MS=.0093396

GROUPING	MEAN	N	SEEDING
A	0.446413	12	3
B	0.304718	12	2
B			
B	0.225589	13	1

ALPHA LEVEL=.05 DF=18 MS=0.002371

GROUPING	MEAN	N	SEEDING
A	0.247379	12	3
B	0.194290	12	2
C	0.146545	12	1

ALPHA LEVEL=.05 DF=11 MS=0.001088

GROUPING	MEAN	N	SEEDING
A	0.071300	9	1
A			
A	0.058288	11	2
B	0.017144	7	3

[1/] Seeding treatment regimes are illustrated on Figure 6-3.

seeding rate). Coverage for green needlegrass was significantly lower on areas seeded at 28 kg/ha than those seeded at the lower rates. It is possible that green needlegrass is being outcompeted by the wheatgrass species in areas seeded at rates exceeding 22 kg/ha.

Significant first and second order interactions are also noted for green needlegrass (Table 6-49). It is probable that the seeding main effect is influential in determining the significant interactions. In addition to the seeding main effect, pubescent wheatgrass appears to be influenced by substrate (Table 6-49). A Duncan's Multiple Range Test indicates that coverage is significantly higher on the control side of the plot (Substrate 1) than the treatment side (Substrate 2) (Table 6-51). It is unclear why coverage varies between substrates when there appear to be no significant differences in soil chemistry or electrical conductivity.

In the context of all treatment years, the coverage of planted grasses on Plot R-3 was highest during 1979 (28.8 percent) and has decreased slightly since that time (24.7 percent in 1980 and 22.7 percent in 1981; Table 6-52). The decreased coverage noted during 1980 and 1981 is a result of aboveground biomass sampling during the 1979 growing season (coverage estimates in subsequent years were made on the same quadrats upon which biomass was measured in 1979).

Statistical comparisons of coverage for planted grasses among years indicate that the planted grass cover reductions during 1980-1981 are significant (Table 6-53). Results of a Duncan's Multiple Range Test indicate that planted grasses have significantly higher coverage during 1979 than any other year (Table 6-54). It is interesting to note that, concomitant with reduced coverage of planted species, the coverage of invading grasses is significantly higher in 1980 than during any other year. Reduced competition after clipping in 1979 may have allowed invading species to become established. It is expected that, as planted species increase in coverage in future years, these invading species will be outcompeted. These data may have range management implications for reclaimed areas during commercial operations. Grazing prior to bond release could be expected to result in reduced coverage of

Table 6-51. Results of a Duncan's Multiple Range Test for Significant Differences in Arcsine Transformed Coverage Estimates Between Substrate Types for Pubescent Wheatgrass During 1981 on Plot R-3, Tract C-a[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=18 MS=0.002371

GROUPING	MEAN	N	SUBSTRAT
A	0.236878	18	2
B	0.155265	18	1

[1/] Substrate treatment regimes are illustrated on Figure 6-3.

Table 6-52. Comparison of Coverage (%) Among Years for Experimental Revegetation Plot R-3, Tract C-a

Growth Form	Year				
	1977	1978	1979	1980	1981
Grasses Planted	5.6	14.0	28.8	24.7	22.7
Grasses Invaded	0.8	0.5	1.5	3.4	3.0
Forbs Planted	8.0	5.1	3.5	4.0	7.3
Forbs Invaded	1.2	0.6	0.9	0.4	0.3
Shrubs Planted	4.7	7.2	16.7	4.0	4.4
Shrubs Invaded	0.0	0.1	0.2	0.1	0.2
TOTAL	20.3	27.5	51.6	36.6	37.9

Table 6-53. Results of a One-Way ANOVA Comparing Arcsine Transformed Coverage Estimates of Planted and Invaded Grasses, Forbs, and Shrubs for 1977, 1978, 1979, 1980, and 1981 for Experimental Revegetation Plot R-3, Tract C-a[1/]

Growth Form	Source of Variation Year	
	F	PR>F [2/]
Grasses Planted	21.02**	0.0001
Grasses Invaded	4.48**	0.0021
Forbs Planted	3.37**	0.0104
Forbs Invaded	0.73	0.5756
Shrubs Planted	17.13**	0.0001
Shrubs Invaded	0.86	0.4449

** Significant at $\alpha = 0.025$

[1/] Complete analyses are presented in Appendix 6-1.6.

[2/] Represents the significance probability (α) associated with F.

Table 6-54. Duncan's Multiple Range Test Results for Significant Differences in Arcsine Transformed Coverage Estimates Among Years for Planted (first listing) and Invaded (second listing) Grasses on Experimental Revegetation Plot R-3, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=420 MS=.0018068

GROUPING	MEAN	N	YEAR
A	0.066819	78	79
B	0.052615	85	80
B			
C B	0.046508	88	81
C			
C	0.034345	84	78
D	0.010779	90	77

ALPHA LEVEL=.05 DF=118 MS=3.0E-04

GROUPING	MEAN	N	YEAR
A	0.024482	25	80
B	0.014214	38	81
B			
B	0.010126	27	79
B			
B	0.006111	18	77
B			
B	0.005000	15	78

planted species while allowing for establishment of non-seeded species, which may influence ultimate reclamation success.

Coverage of planted forb species on all treatment combinations for the control plots ranged from 2.3 to 17.5 percent and averaged 8.9 percent. Mean coverage on plots underlain by processed shale was somewhat lower (5.7 percent) and ranged from 2.3 to 9.3 percent. Planted forb coverage on both the control and treatment portions of the study site was highest on the plots which were hydromulched and seeded at the lowest rate--17 kg/ha (Table 6-46). Cicer milkvetch (Astragalus cicer) was the dominant forb throughout the study area; however, Lewis flax (Linum lewisii) and yellow sweetclover (Melitotus officinalis) were subordinate forbs occurring commonly on both the control and treatment portions of the area (Appendix 6-1.3). The most prevalent invading forbs were twinpod (Physaria floribunda), scarlet globemallow (Sphaeralcea coccinea), and cryptantha (Cryptantha sericea).

Based on 1981 estimates, the results of a three-way ANOVA comparing coverage for all planted and/or invaded forbs on various treatment combinations (substrate, mulch, and seeding rate) indicate that there are no significant differences (Table 6-47). These results represent a departure from 1980 data which showed significant differences for planted forb species based on seeding rate. It is possible that reduced competition from grasses subsequent to the 1979 clipping for biomass determinations has allowed for a more even distribution of forbs throughout all seeding treatments.

When coverage of individual forb species is compared among the three main treatment effects, significant differences in coverage of cicer milkvetch are noted between the shale and no shale substrates, and among seeding rates (Table 6-49). The results of a Duncan's Multiple Range Test illustrate that coverage is significantly higher on the control portion (no shale) of the site (Table 6-55). A similar circumstance was noted during 1980. It is unclear why coverage varies between the shale and no shale substrates. Since there appear to be no significant differences in soil chemistry between the areas (RBOSC 1981a), it is possible that the variations are artifacts of the sampling rather than a result of processed shale effects. Coverage was significantly higher on areas seeded at 17 kg/ha than those seeded at the

Table 6-55. Results of a Duncan's Multiple Range Test for the Significant Difference in Arcsine Transformed Coverage Estimates Between Substrate (first listing) and Among Seeding Rates (second listing) for Cicer Milkvetch During 1981[1/]

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=18 MS=.0128754

GROUPING	MEAN	N	SUBSTRAT
A	0.242777	18	1
B	0.160724	18	2

ALPHA LEVEL=.05 DF=18 MS=.0128754

GROUPING	MEAN	N	SEEDING
A	0.247865	13	1
A			
B A	0.214870	12	2
B			
B	0.132940	11	3

[1/] Substrate and seeding treatment regimes are illustrated on Figure 6-3.

highest rate--28 kg/ha (Table 6-55). These differences possibly are a result of increased competition from grasses on areas seeded at the high rate.

Table 6-52 indicates that planted forb cover has increased following clipping of the quadrats for biomass determinations. This increase may be a result of decreased competition from grass species. It is interesting to note that coverage during 1981 is similar to that recorded during 1977. High coverage during the first growing season also may have been the result of low competition from grass species.

Based on the above data, it is not surprising that there are significant differences in coverage of planted forbs among years (Table 6-53). A Duncan's Multiple Range Test indicates that the 1981 planted forb coverage, though similar to 1980, was significantly higher than any of the other years (Table 6-56). Although coverage during 1977 was greater than in any other year, the 1977 data are grouped with 1978, 1979, and 1980 data due to an artifact of the arcsine transformed weighted means used in the Duncan's Multiple Range Test.

Coverage of planted shrubs on the control portion of the study area during 1981 averaged 4.2 percent and ranged from 0.2 to 8.0 percent. The corresponding coverage on the treatment portion averaged 4.6 percent, ranging from 0.8 to 7.8 percent (Table 6-46). The greatest coverage on the control portion was found on plots that were seeded at 22 kg/ha and hydromulched, whereas seeding at 28 kg/ha followed by hydromulching resulted in the highest coverage on the treatment area. The mean coverage of invaded shrub species was low--0.3 and 0.2 percent for control and treatment areas, respectively. Winterfat (Ceratoides lanata) and fourwing saltbush (Atriplex canescens) were the dominant planted shrub species. Bitterbrush (Purshia tridentata) was encountered on many plots but contributed only a minor amount to shrub coverage. Broom snakeweed (Gutierrezia sarothrae) was the most common invading shrub species encountered on both the control and treatment portions of the site.

A comparison of total shrub coverage over all treatment combinations for 1981 shows that there are no significant differences among the substrate, mulch,

Table 6-56. Results of a Duncan's Multiple Range Test for the Significant Difference in Arcsine Transformed Coverage Estimates Among Years for Planted Forbs on Experimental Revegetation Plot R-3, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=291 MS=6.7E-04

GROUPING	MEAN	N	YEAR
A	0.041195	74	79
B	0.017587	71	78
B			
B	0.015461	51	81
B			
B	0.009764	70	77
B			
B	0.008557	30	80

or seeding main effects tested (Table 6-47). When individual shrub species are considered, a three-way ANOVA again indicates that there are no significant differences in coverage based on the main effects tested (Table 6-49).

Shrub coverage of planted species on the quadrats sampled has declined from a high of 16.7 percent in 1979 to 4.4 percent in 1981 (Table 6-52). This reduction in coverage is a result of destructive sampling conducted at the end of the 1979 growing season. A comparison of shrub coverage among years indicates that significant differences exist (Table 6-53). The results of a Duncan's Multiple Range Test show that planted shrub coverage in 1979 was significantly higher than during any of the other years (Table 6-57). Because shrub species are not expected to readily produce growth from root-stocks as do many grasses and forbs, the planted shrubs on Plot R-3 are not responding to destructive sampling as well as grasses or forbs. Data for 1980 and 1981 cannot be deemed representative of portions of the study plot which were not impacted by clipping in 1979. Assessments of coverage and biomass scheduled for 1982 will provide data on undisturbed portions of the study area.

b. Precipitation at Plot R-3 - Average rainfall data, based on two sampling locations at Plot R-3, are listed in Table 6-58. Mean precipitation from April-October 1981 was 9.6 inches, with the highest monthly total occurring during July. Total rainfall during the 1981 growing season was higher than for any of the four other years of record. The pronounced lack of precipitation (typical from mid-June through mid-July) was not evident during the 1981 season.

c. Soil Chemistry at Plot R-3 - Soil samples were collected during September 1981 and analyzed for electrical conductivity (EC) during October 1981. These data are presented in Table 6-59. Statistical comparisons between EC values for control and treatment substrates show that, for any given year and sample depth, there are no significant differences based on substrate (Appendix 6-1.6). As expected, EC does increase with depth in the reconstructed profile, probably as a result of the increased amount of unweathered parent material. Fluctuations evident among years for a given sample depth are thought to be artifacts of sampling and/or analytical techniques.

Table 6-57. Results of a Duncan's Multiple Range Test for Significant Differences in Arcsine Transformed Coverage Estimates Among Years for Planted Shrubs on Experimental Revegetation Plot R-3, Tract C-a

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=291 MS=6.7E-04

GROUPING	MEAN	N	YEAR
A	0.041195	74	79
B	0.017587	71	78
B			
B	0.015461	51	81
B			
B	0.009764	70	77
B			
B	0.008557	30	80

Table 6-58. Average Rainfall (in.) Recorded at Experimental Revegetation Plot R-3 from 1977-1981, Tract C-a[1/]

Month	Year					
	1977	1978	1979	1980	1981	Mean
April	0.36	0.63	0.47	1.14	0.35[2/]	0.59
May	0.59	1.30	2.72	1.65	1.34	1.52
June	0.28	0.83	0.47	0.04	1.18	0.56
July	1.30	0.55	0.83	1.06	2.24	1.20
August	2.28	0.67	0.87	2.72	1.42	1.59
September	0.98	0.63	0.47	0.67	1.22	0.79
October	1.26	0.20	1.06	0.98	1.85	1.07
Total	7.05	4.81	6.89	8.26	9.60	7.32

[1/] Rainfall is averaged for upper and lower gauges.

[2/] Data are from the wedge gauge at Meteorological Site 2.

Table 6-59. A Comparison of Mean Electrical Conductivity (mmhos/cm) Between Control (No Shale) and Treatment (Shale) Substrates[1/]

Substrate	Depth (cm)	Year					
		1976	1977	1978	1979[2/]	1980[2/]	1981
Control	0	0.26	0.20	0.28	0.18	0.23	0.16
	25	0.31	0.26	0.27	0.23	0.25	0.18
	50	0.56	0.57	0.42	0.51	0.42	0.24
Treatment	0	0.28	0.20	0.26	0.23	0.27	0.18
	25	0.38	0.26	0.28	0.33	0.27	0.17
	50	0.45	0.50	0.40	0.32	0.36	0.26

[1/] EC is based on a 1:2 soil-water extract.

[2/] Data are converted to values which correspond to a 1:2 soil-water extract.

Electrical conductivity data suggest that the rubblized overburden materials within the reconstructed soil profile are continuing to prevent capillary migration of dissolved salts from the processed shale into the surface growth medium. An assessment of root interaction within the barrier will be undertaken during 1982 to determine if there is root interaction with the processed shale.

C. Experimental Revegetation Greenhouse Studies

1. Objectives

During commercial operations at Tract C-a, surface retorts will produce large amounts of processed shale. This material will require surface disposal because not all the material could be returned to in-situ retorts and/or an open pit mine. Although a number of studies have been conducted to determine the chemical characteristics of processed shale, waste materials from various retorting processes are expected to differ considerably. Therefore, greenhouse studies were initiated in 1980 to assess the revegetation potential of Lurgi processed shale. These studies were conducted for RBOSC by Native Plants, Inc. (Ostler 1981).

The objectives of the greenhouse study were (1) to determine concentrations of boron (B), molybdenum (Mo), fluorine (F), arsenic (As), and selenium (Se) in plants grown in Lurgi processed shale and in barriers of various depths of topsoil and subsoil over the Lurgi processed shale; (2) to determine plant growth and response in various growth mediums, using techniques including biomass measurements of roots and shoots; (3) to investigate the suitability of Lurgi processed shale as a medium for seed germination; and, (4) to assess the potential of stockpiled Tract C-a topsoils to infect roots with beneficial vesicular-arbuscular mycorrhizal (VAM) fungi.

2. Methods

To assess the influence of varying topsoil/subsoil depths and capillary barriers on plant growth and trace element uptake, 11 variations of topsoil, subsoil, and capillary barrier depths over Lurgi processed shale, including

two topsoil controls and one shale-only treatment, were tested. The treatments were as follows:

1. 15 cm topsoil (control)
2. 30 cm topsoil (control)
3. 15 cm shale
4. 15 cm topsoil, 15 cm shale
5. 15 cm topsoil, 15 cm subsoil barrier, 15 cm shale
6. 15 cm topsoil, 30 cm subsoil barrier, 15 cm shale
7. 30 cm topsoil, 15 cm shale
8. 30 cm topsoil, 15 cm subsoil barrier, 15 cm shale
9. 30 cm topsoil, 30 cm subsoil barrier, 15 cm shale
10. 15 cm topsoil, 15 cm gravel barrier, 15 cm shale
11. 15 cm topsoil, 30 cm gravel barrier, 15 cm shale

Five species; pubescent wheatgrass (Agropyron trichophorum), Indian ricegrass (Oryzopsis hymenoides), Lewis flax (Linum lewisii), fourwing saltbush (Atriplex canescens), rubber rabbitbrush (Chrysothamnus nauseosus), representing the lifeforms dominant in the oil shale regions, were grown in separate pots containing the aforementioned treatments.

The plants were grown for six months during which time several evaluations of plant growth were made. After this period, the plants were harvested, dried, weighed and sent to Western Analytical Laboratory for analysis of B, Mo, F, As, and Se. Roots were taken from selected treatments and examined for mycorrhizal infection.

Fifty-five seeds from 12 species were sown at various depths in five replicated flats containing Lurgi processed shale. Conditions (light, moisture, etc.) were kept at an optimal state and the number of germinating seeds was recorded during a 38-day period.

3. Results and Discussion

Several basic conclusions can be drawn from these experiments, particularly as they relate to the objectives of this study and the suitability of topsoiling processed shale for revegetation.

a. Growth Evaluation - The differential response of plants grown in the various treatments shows that all of the treatments with 30 cm of topsoil were superior to those with only 15 cm of topsoil. Adding a layer of subsoil as a barrier improved plant growth. However, there was no significant difference among the treatments with 15 cm and 30 cm of subsoil barrier, or among those with the 15 cm and 30 cm topsoil depth over the subsoil. The Lurgi shale underlying topsoil did not appear to hinder plant growth.

The use of pea gravel as a capillary barrier likewise produced no significant differences between the 15 cm topsoil control and the two gravel barrier treatments. The gravel was much more restrictive to root growth than the subsoil barrier. However, roots still penetrated the 30 cm gravel barrier and were in contact with the processed shale at the termination of the experiment. The shale-only treatment consistently had the lowest favorability index, and aboveground and root biomass.

The relative performance exhibited by native plant species growing in the treatments, as indicated by the favorability index, correlated closely with that of aboveground biomass. This is particularly important because the index, which is a calculated value based on leaf number and length, is a nondestructive measure and thus can be utilized to monitor plant performance over time without clipping the plants, a practice which would result in eventual termination of the experiment. Production of root biomass was not significantly different among treatments due to greater variation among species in this parameter. Average aboveground production was nearly identical among the five species tested, although A. trichophorum was slightly higher than the other species.

b. Trace Element Movement - The migration of B, Mo, and F from the shale into the overlying soils due to capillary action did not appear to occur, or at least was not detectable, under the conditions of the study. Results from the treatments tested showed differences only between the type of material that was overlying the shale, i.e. topsoil or subsoil barrier. There actually appeared to be losses of the water soluble B, Mo, and F from the overlying soils due to leaching. Leaching was also apparent in the processed shale, where the concentration of water soluble B was less than

that observed in the baseline analysis. The concentrations of water soluble Mo or F did not change significantly.

A reduction in the electrical conductivity, from the levels observed in the baseline analyses of soils and those determined after the study, showed that a loss of salts occurred from both the topsoil and subsoil despite the fact that they were underlain by shale.

The availability of B and Mo to plants appears to be very sensitive to the method of shale retorting judging from the results of other studies. The U. S. Bureau of Mines (USBM) process produces a spent shale which is low for B and high for Mo, while the reverse is true for the TOSCO process. The Lurgi process, however, appears to produce shales low in both B and Mo. Boron concentrations in the dried plant material averaged 3.0 ppm for the control, 2.7 ppm for the different soil treatments over shale, and 3.9 ppm for the shale only treatment. None of the treatments or the controls exhibited significantly different boron concentrations ($\alpha \leqq 0.05$). However, a statistical test showed that the grasses absorbed far less B than the shrubs or the one forb species tested. Even the highest values of B among the plants tested were well within the tolerable level for plant growth and animal uptake.

Molybdenum also occurred in relatively low values in the plants grown in all treatments. Significant differences in molybdenum concentrations ($\alpha \leqq 0.05$) did occur between the controls (15 and 30 cm topsoil only) and the shale only treatment, and the 15 cm topsoil over 15 cm shale treatment. The other treatments were all intermediate with no obvious trends in Mo content in relation to soil depth or type of barrier. Average Mo values in the controls and the other treatments were roughly equivalent to values reported in similar studies involving different processes for oil extraction from the shale. There were significant differences among species in their uptake of Mo. A. canescens exhibited highest values and C. nauseosus the lowest. C. nauseosus contained approximately 30 percent of the average value of Mo as found in A. canescens.

The fluorine content of plants grown in straight Lurgi processed shale was very high, with average concentrations ($\bar{x}$ = 42.5 ppm) approaching excessive levels, as defined by Gough (1979). This F content of A. trichophorum and O. hymenoides could pose serious problems for plant and livestock welfare. However, the fluorine content dropped drastically when even 15 cm of topsoil was placed over the shale. With this treatment, the F levels were reduced to near the average values for the controls (15 cm and 30 cm of topsoil only). The soil apparently acts as a sink for the F, which is tied up quickly and becomes relatively unavailable to plants.

Selenium apparently reacts in much the same manner as fluorine. The Se level in plants grown in straight shale is very high (13.8 ppm) and exceeds normal levels as noted by Gough et al. (1979). The results for Se are based on only one composite sample of plant tissue from all five species because of the lack of plant growth in the treatment. The Se concentrations drop markedly with even an application of 15 cm of topsoil over the shale and are further reduced (to half) with an additional 15 cm of topsoil or subsoil barrier. There appear to be no problems with Se uptake by the plants if only 15 cm of topsoil is placed over the shale before revegetation, at least for the time period considered in this study.

Low levels of arsenic (less than one ppm) were measured in all plants and treatment profiles analyzed. Levels were comparable to other research findings and appear to offer no potential problems for plant growth or for grazing animals.

c. Seed Germination - Seed germination tests showed very poor performance of seeds sown in or on Lurgi processed shale. The three depths of plantings (surface, 1 cm, and 2.5 cm) resulted in no significant difference ($\alpha \leq 0.05$) in germination response. The results from these three depth treatments were statistically different from the control (topsoil with seeds planted at 1 cm) as tested by Analysis of Variance and Fisher's LSD.

d. Mycorrhizal Infection - Under greenhouse conditions, topsoils from Tract C-a which had been stockpiled for three years naturally inoculated A. trichophorum, A. canescens, C. nauseosus, L. lewisii, and O. hymenoides

seedlings with VAM fungi. Species differed in the degree to which their roots became colonized, but after six months, A. trichophorum, C. nauseosus, L. lewisii, and O. hymenoides were more than 50 percent mycorrhizal. A. canescens showed a lower level of infection--20-percent. Thus, Tract C-a soil stockpiled for three years provides a suitable growth medium for VAM forming plants. Results further showed that underlying shales and capillary barriers had no discernible impact on VAM formation in Tract C-a topsoils. Vesicular-arbuscular mycorrhizal fungi have been shown to greatly enhance the growth and survival of plants on reclaimed mined lands, and the degree to which mycorrhizae form within Tract C-a materials may be a key to revegetation success on the site.

6.2 TOXICOLOGY

Extensive toxicological and industrial hygiene studies are being conducted by the U. S. Department of Energy (DOE) Oil Shale Task Force and RBOSC on products and by-products of oil shale retorting. DOE studies have concentrated on Modified In Situ (MIS) operations, while RBOSC studies have included both MIS and Lurgi materials.

1. Objectives

The objectives of the DOE and RBOSC-sponsored research are as follows:

- Characterize the chemical and physical properties of the raw shale and the products and by-products of the retorting processes to determine the potential effects of these materials.

- Determine the biological activity (carcinogenicity, mutagenicity, teratogenicity, and toxicity) of oil shale products and by-products to assess their potential exposure to workers and their potential environmental hazards.

- Develop an industrial hygiene program, control procedures and technology to mitigate or prevent worker exposure and environmental hazards associated with oil shale, its products, and by-products.

2. Methods

Studies conducted by the DOE were designed to characterize the liquid, gaseous, and solid products and by-products in the worker environment before and after the ignition of RBOSC's MIS retort Zero. The types of materials sampled are listed below:

- Liquid

  - Sour water (separator room)
  - Sour water (knockout drum)

- Scrubber water
- East Retention Pond water
- Crude shale oil
- Surface water
- Ground water

- Gaseous

  - Mine air
  - Retort off gas

- Solids

  - Mine dust
  - Raw oil shale
  - Soils
  - Stack particulates

The characterization studies provide data to be used in the design and interpretation of health and environmental effects research. DOE sponsored studies are also underway to evaluate the effects of oil shale production on biological organisms including humans. These studies include in vivo toxicity testing, industrial hygiene sampling, and epidemiological research. The health studies for Retort Zero include air sampling in the mine as well as cellular screening tests on oil shale-related materials.

Preliminary toxicology testing of MIS and Lurgi materials has also been undertaken by RBOSC. These tests are being conducted by the IIT Research Institute in Chicago under the direction of Paul Garvin and Kent TeVault, toxicologists, Standard Oil Company (Indiana). Tests conducted to date include acute oral toxicity in rats, acute dermal toxicity in rabbits, skin and eye irritation in rabbits, and the Ames mutagenicity tests. Tests presently underway or to be initiated in the near future include dermal sensitization, acute inhalation toxicity, dermal reproduction, and dermal cytogenetics tests.

3. Results

A draft progress report on the testing conducted for Retort Zero was released by the DOE Oil Shale Task Force in November, 1981. The following is excerpted from that progress report:

- Liquid Samples

  - All of the sour waters analyzed were quite dilute compared to other retort product waters. This dilution may be due to a large inflow of ground water.

  - In spite of the considerable dilution of sour water, several parameters were observed to increase with retorting time: pH, alkalinity, and concentrations of ammonia, organic carbon, conductivity, and molybdenum.

  - Numerous organic compounds were identified in the sour water including a large number of hydrocarbons, carboxylic acids, phenols, cresols, naphthalenes, alkyl pyridines, anilines, and quinolines.

  - The crude shale oil is generally similar to other shale oils with some significant differences. These include a sulfur content about three times higher than other shale oils, higher concentrations of nickel and molybdenum, and a lower concentration of arsenic. These trends have been noticed for other in situ oils but are more pronounced for Retort Zero oil.

- Gaseous Samples

  - The raw off-gas was analyzed for a number of sulfur species. The sulfur compounds identified included hydrogen sulfide, carbonyl sulfide, carbon disulfide, methyl mercaptan, thiophene,

methylthiophene, and sulfur dioxide. The total non-hydrogen sulfide species ranged from 0.9 percent to 4.2 percent of the total sulfur.

- The off-gas mercury concentrations were low at the beginning of the burn; however, they increased rapidly toward the end. This behavior has been observed in laboratory retorts but was not seen with Retort 6 at Logan Wash.

- Radon concentrations in the off-gas were quite low.

- Oxides of nitrogen were measured in the stack gas after the venturi scrubber. The major oxide of nitrogen was nitric oxide with concentrations ranging from 62 to 175 ppm. The concentrations of nitric oxide approximately tripled from the beginning to the middle of the burn and decreased by 30 percent toward the end of the burn.

- Solid Samples

  - Although the elemental analyses, leaching behavior studies, and mineralogical characterization of the raw shale samples are not complete, preliminary data indicate that the results will be useful in understanding the behavior of the raw shale before, during, and after retorting.

  - Soil samples were collected in a 6-km^2 area surrounding the retort and were analyzed for mercury. The results show that there are significant differences in the average mercury concentrations in the soils developed on the Parachute Creek Member, Uinta Formation, and alluvium. Other calculations indicate that this baseline data will allow for an early detection of mercury accumulation by soils if there is significant deposition from retorting.

- Stack particulates were collected and benzene extracted for associated organic compounds. The results indicate that most of the organic material to be polycylic aromatic hydrocarbons (PAH's).

- Industrial Hygiene Studies - Air samples were collected to (1) characterize potential inhalation hazards, (2) provide data for the design of toxicology studies using representative materials, and (3) investigate the existence of unique exposure conditions.

  - Analysis of samples collected at various locations in the "G" level of the mine (835 feet below surface) indicated low concentrations of hydrogen sulfide and particulates (compared to Threshold Limit Values; TLV's). One sample of hydrogen sulfide was at the the TLV, but the sampling duration was only several minutes whereas the TLV was made over an 8-hr exposure period.

  - The measured dust concentrations were all well below the TLV value for dust containing 3 percent quartz. Industrial hygiene studies have been completed for both Retorts Zero and One. A draft report will be available in the near future.

- Toxicology

  The DOE toxicology studies are designed to evaluate the environmental hazard of materials produced by the MIS retorting process. Several waters were subjected to a bioluminescent test which has been shown to correlate with fish toxicity tests. This test indicated some toxicity associated with the sour waters from the underground separator and the knockout drum.

Ames mutagenicity tests were conducted on oil and process waters by both Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL) using slightly different procedures. LANL found no mutagenic activity in any water sample, but they noted a cytotoxic response with sour water from the scrubber and with the holding pond water. LLNL found a positive mutagenic activity in waters from the underground separators and the knockout drum.

Both the mutagenic activity as measured by the Ames assay and the sister chromatid exchanges induced by the dimethylsulfoxide (DMSO) extract of the crude oil yielded positive results.

The status of the tests being conducted at the IIT Research Institute laboratory, as of December 31, 1981, is included in Table 6-60. The results of these tests and the DOE Oil Shale Task Force tests will be updated when final results are available.

Table 6-60. Status of Toxicity Testing on RBOSC Test Materials, December 31, 1981

Test Material	Test	Status
Spent Shale	Acute Oral Toxicity	Report undergoing review
	Eye Irritation	Report due
	Acute Dermal Toxicity	Report undergoing review
	Ames Test	Report undergoing review
	Unscheduled DNA Synthesis	Report draft due 12/28/81
	Forward Mutation Assay	Work in progress
	Dermal Cytogenetics	Work in progress
Mahogany Shale	Acute Oral Toxicity	Report in preparation
	Acute Dermal Toxicity	Report undergoing review
	Ames Mutagenicity	Report in preparation
	Unscheduled DNA Synthesis	Report draft due 12/28/81
	Forward Mutation Assay	Work in progress
	Dermal Cytogenetics	Work in progress
Raw MIS Shale Oil	Acute Oral Toxicity	Report in preparation
	Eye Irritation	Report under review
	Dermal Irritation	Report due
	Acute Dermal Toxicity	Report undergoing review
	Dermal Sensitization	Scheduled
	Ames Mutagenicity	Report undergoing review
	Unscheduled DNA Synthesis	Report draft due 12/28/81
	Forward Mutation Assay	Work in progress
	Dermal Cytogenetics	Work in progress

Table 6-60. Continued

Test Material	Test	Status
MIS Retort Sour Water	Acute Oral Toxicity	Report in preparation
	Eye Irritation	Report under review
	Dermal Irritation	Report due
	Acute Dermal Toxicity	Report in preparation
	Dermal Sensitization	Scheduled
	Ames Mutagenicity	Report under review
	Unscheduled DNA Synthesis	Report draft due 12/5/81
	Forward Mutation Assay	Work in progress
	Dermal Cytogenetics	Work in progress
MIS Recirculated Retort Water	Acute Oral Toxicity	Report in preparation
	Eye Irritation	Report undergoing review
	Dermal Irritation	Report due
	Acute Dermal Toxicity	Report in preparation
	Dermal Sensitization	Work in Progress
	Ames Mutagenicity	Scheduled
	Unscheduled DNA Synthesis	Report draft due 12/5/81
	Forward Mutation Assay	Work in progress
	Dermal Cytogenetics	Work in progress
Lurgi Retort Water	Acute Oral Toxicity	Report in preparation
	Eye Irritation	Report undergoing review
	Dermal Irritation	Report undergoing review
	Acute Dermal Toxicity	Report in preparation
	Dermal Sensitization	Work in progress
	Ames Mutagenicity	Scheduled
	Unscheduled DNA Synthesis	Report draft due 12/5/81
	Forward Mutation Assay	Work in progress
	Dermal Cytogenetics	Work in progress

Table 6-60. Continued

Test Material	Test	Status
Heavy Lurgi Shale Oil	Acute Oral Toxicity	Report in preparation
	Eye Irritation	Report due
	Dermal Irritation	Report due
	Acute Dermal Toxicity	Report in preparation
	Dermal Sensitization	Scheduled
	Dermal Reproduction	Range-finding work underway
	Ames Mutagenicity	Scheduled
	Unscheduled DNA Synthesis	Report draft due 12/30/81
	Forward Mutation Assay	Work in progress
	Dermal Cytogenetics	Work in progress
Middle Lurgi Shale Oil	Acute Oral Toxicity	Report in preparation
	Eye Irritation	Report under review
	Dermal Irritation	Report in preparation
	Acute Dermal Toxicity	Report in preparation
	Dermal Sensitization	Work in progress
	Dermal Reproduction	Range-finding work underway
	Ames Mutagenicity	Scheduled
	Unscheduled DNA Synthesis	Report draft due 12/30/81
	Forward Mutation Assay	Work in progress
	Dermal Cytogenetics	Work in progress
Light Lurgi Shale Oil	Acute Oral Toxicity	Report in preparation
	Eye Irritation	Report undergoing review
	Dermal Irritation	Report undergoing review
	Acute Dermal Toxicity	Report undergoing review
	Dermal Sensitization	Work in progress
	Acute Inhalation Toxicity	Report in preparation
	Dermal Reproduction	Range-finding work underway
	Ames Mutagenicity	Scheduled
	Unscheduled DNA Synthesis	Report draft due 12/30/81
	Forward Mutation Assay	Work in progress
	Dermal Cytogenetics	Work in progress

6.3 RUN-OF-MINE LYSIMETER

RBOSC, in cooperation with the EPA, the USGS, and the DOE Task Force, is conducting leaching studies on stockpiled run-of-mine ore. As a part of this agreement, RBOSC constructed the leaching apparatus in the stockpile. The cooperating government groups will collect and analyze the leachate.

The objectives of this study are to determine the chemical characteristics of leachate generated from raw shale in the field and to compare these results with those from laboratory tests on the same materials. This comparison is being conducted to determine the importance of such factors as percolation rates (residence time), wetting and drying cycles, and other weathering factors on leachate quality.

The field collection system consists of three collectors buried beneath the raw shale pile at depths of 5, 10, and 15 feet. Each collector consists of 10 feet x 10 feet square Teflon sheet, contoured so that the percolating water is intercepted and conducted to a Teflon drainpipe located at the center of the collector (Figure 6-4). Collectors are constructed so that leachate is collected sequentially in a series of five containers (three 2-liter and two 40-liter). As one container is filled, leachate is routed to the next container in the sequence.

A flow-through electrical resistance probe and a thermocouple have been placed in the Teflon collection line to measure conductivity and temperature. Recording rain gauges document precipitation quantity in the area of the pile. Snow depths are periodically recorded.

The field lysimeter tests were initiated in mid-June, 1980. The results of the tests, both leachate volumes and chemical analyses, wre published by Dr. David McWhorter (1981). A summary of this report was included in MDP 8. Since May 31, 1981, additional samples have been collected and analyzed. The lysimeters have been monitored only for volume (no sampling) since November 1981. Publication of a second annual progress report is expected in the spring of 1982. The relevant portions of the forthcoming report will be included in the next MDP monitoring report.

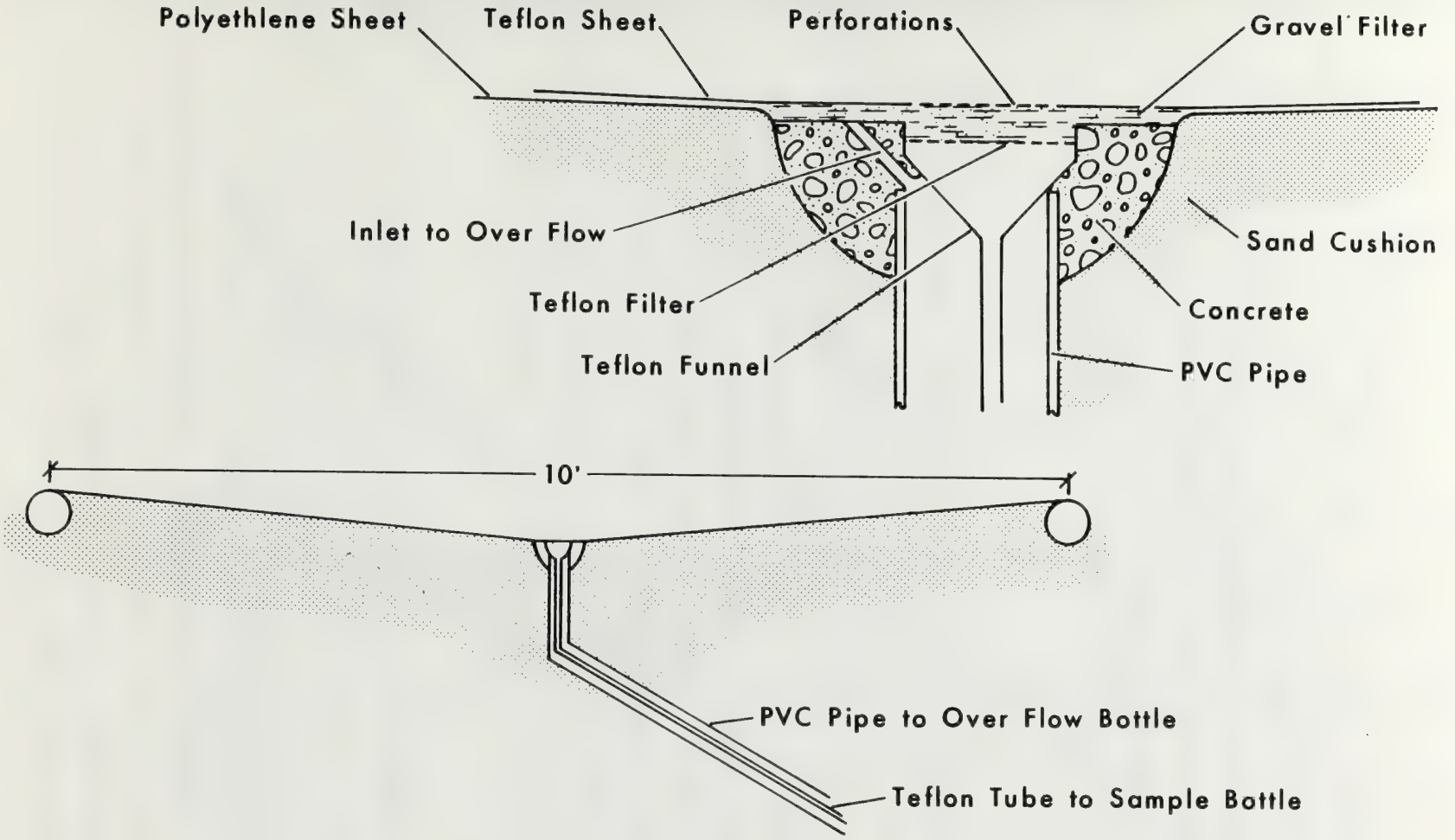


Figure 6-4. Construction Details of the Buried Collectors - Tract C-a.

6.4 MULE DEER HABITAT MODIFICATION STUDY

1. Objectives

During RBOSC's commercial operation, disturbances of the land will result in the loss of forage for wildlife, primarily mule deer. One means of mitigating these losses is to increase the mule deer carrying capacity of undisturbed areas to maintain the overall carrying capacity at, or near, predevelopment levels. RBOSC initiated an experiment in 1980 to determine the feasibility of producing such increases in carrying capacity using the habitat modification techniques described below.

2. Methods

The critical factor which currently limits mule deer populations in the Piceance Creek Basin is the availability of suitable food during periods of heavy snow cover. Thus, a program designed to increase the carrying capacity of local habitats for mule deer should be aimed at increasing suitable forage as well as providing access for mule deer to these modified areas during periods of heavy snow cover. Habitat modification in large, continuous blocks increases wildlife forage, but such large areas commonly fill with snow during periods of heavy snowfall making the area inaccessible to deer. The RBOSC habitat modification program is designed to avoid this problem by modifying vegetation in strips, leaving the vegetation between strips undisturbed. The undisturbed strips provide cover and access routes to the modified areas.

The 1980 habitat modification experiment was established October 22-23 in the SE¼, SE¼ of Section 1, T2S, R99W in Stake Springs Draw (Figure 6-5). This area includes a valley bottom with dense, uniform sagebrush, a south-facing slope offering several browse species palatable to mule deer and a travel lane between the bedding area and feeding area, and a north-facing slope characterized by desirable forage species. The experiment was designed to evaluate the effects of several factors critical to increasing deer carrying capacity: (1) snow depth, (2) moisture availability during the growing season, (3) selective brush removal, (4) quality forage, and (5) fertilization.

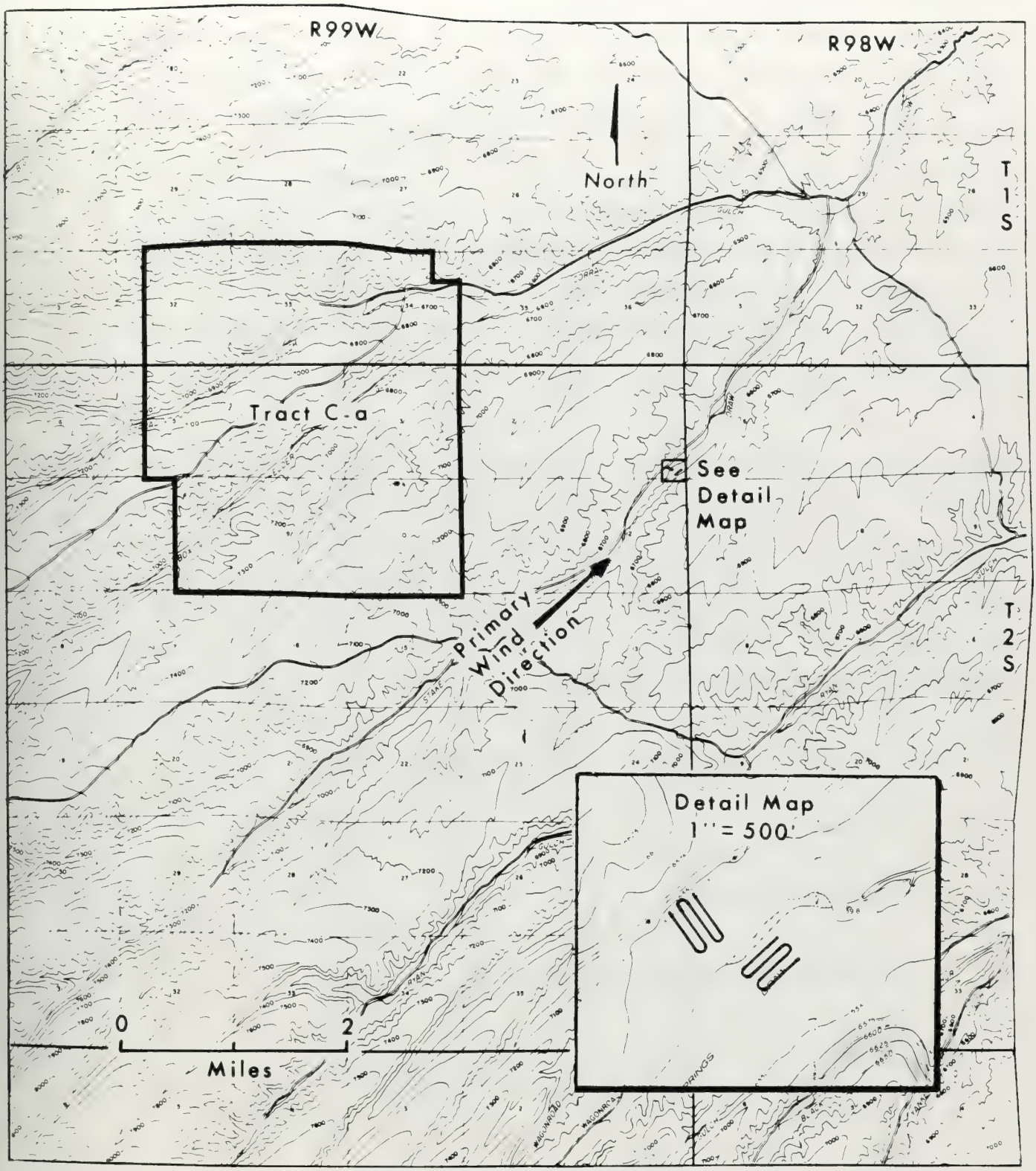


Figure 6-5. Location of Mule Deer Habitat Modification Study

To increase desirable forage production, it was necessary to remove the rank sagebrush, in order to reduce plant competition. To do this, two Marden Model L-7 roto-choppers (filled with water for additional weight) were pulled behind a John Deere 450 dozer. Four 5-m corridors were chopped in each of two treatment areas within the valley bottom (Figure 6-6 and 6-7). The coorridors in the treatment area adjacent to the south-facing slope were oriented perpendicular to the draw and the direction of most winter winds (NW-SE). Corridors in the treatment area adjacent to the north-facing slope were aligned parallel to the direction of most winter winds (NE-SW). A differential accumulation of snow should occur between the two areas, thereby enabling an evaluation of the effects of such accumulation on forage production and utilization as well as deer movement.

Half of each treatment area parallel to the corridors was seeded, as shown in Figure 6-7. The treated corridors and the untreated sagebrush zones between them were broadcast seeded with the seed mixture proportions illustrated on Table 6-61. Half of each treatment area perpendicular to the corridors were fertilized with ammonium nitrate (33.4% nitrogen) at 120 pounds per acre, in the spring of 1981 (Figure 6-7). Both the chopped corridors and the undisturbed sagebrush between them were fertilized.

The treatment regimes which were established are as follows:

- chopped
- chopped and seeded
- chopped, seeded, and fertilized
- chopped and fertilized
- unchopped
- unchopped and seeded

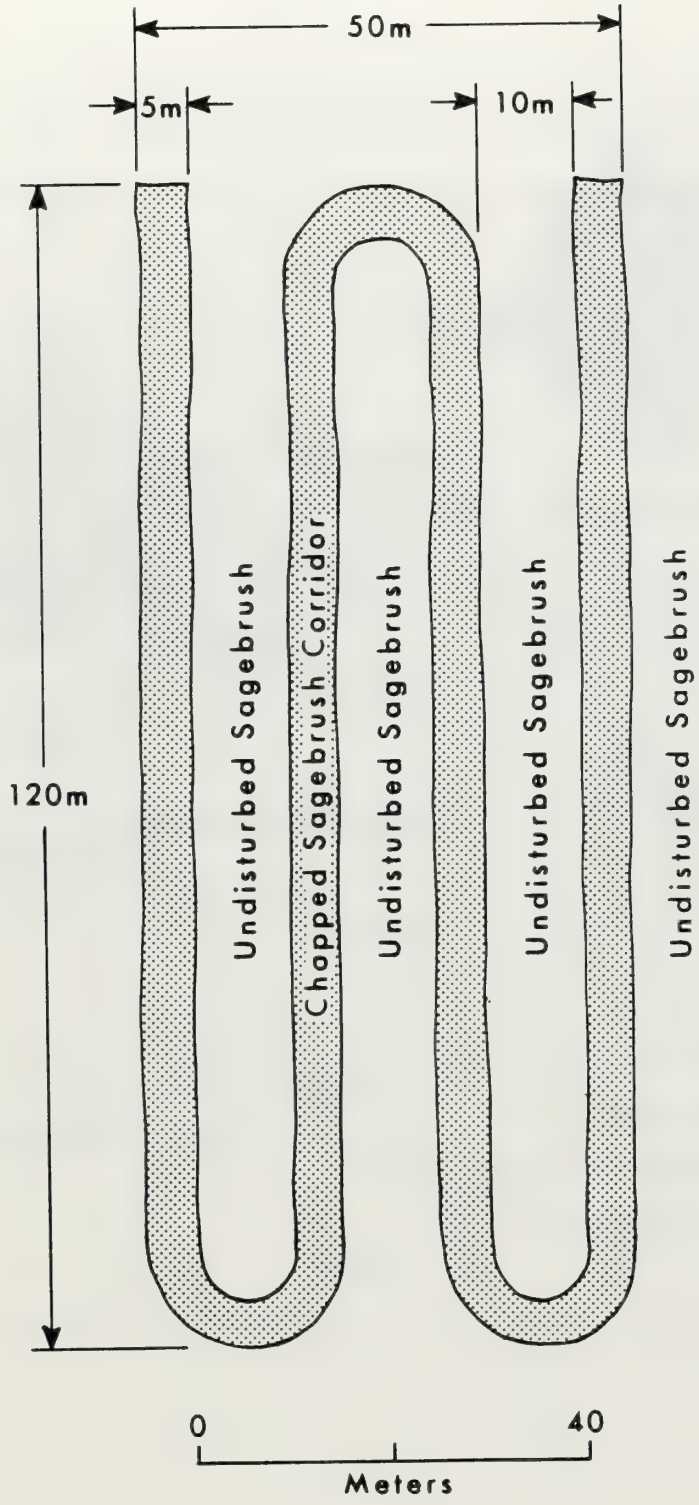


Figure 6-6. Configuration of Roto-Chopped Corridors in Area of Uniform, Dense Sagebrush in Stake Springs Draw.

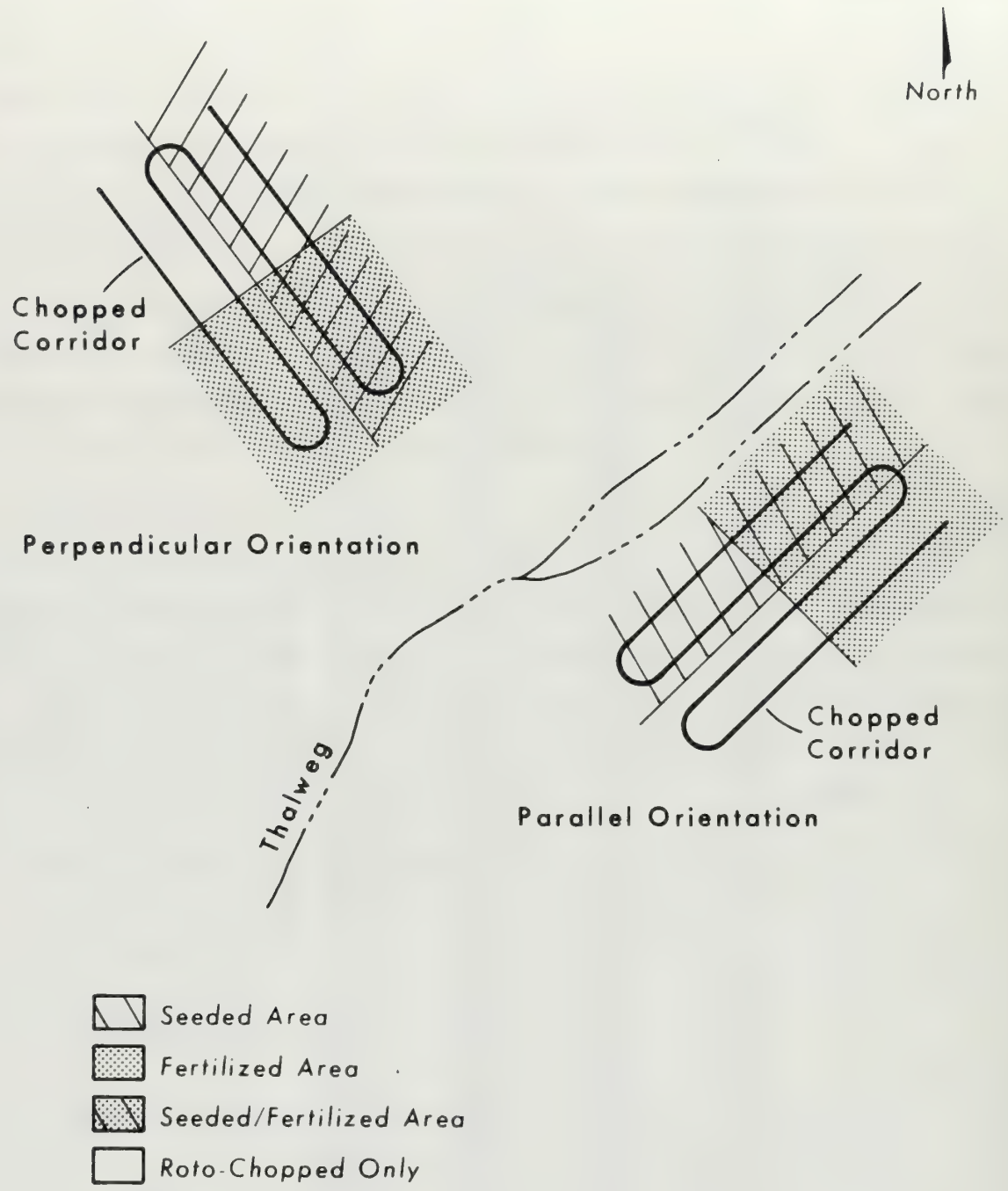


Figure 6-7. Configuration of Seeding & Fertilizing Treatments in Deer Mitigation Study.

Table 6-61. Plant Species Broadcast Seeded in the Roto-Chop Experiment Area in Stake Springs Draw

Species	Pounds Per Acre	
Grasses		
Crested wheatgrass (Agropyron desertorum)	2	
Pubescent wheatgrass (Agropyron trichophorum)	1	
Western wheatgrass (Agropyron smithii)	3	
Indian ricegrass (Oryzopsis hymenoides)	1	
Russian wildrye (Elymus junceus)		5
Subtotal	12	
Forbs		
Alfalfa (Medicago sativa)		3
Cicer milkvetch (Astragalus cicer)		1
Subtotal	4	
Shrubs		
Four-wing saltbush (Atriplex canescens)	2	
Winterfat (Ceratoides lanata)		2
Subtotal	4	
TOTAL	20	

- unchopped, seeded, and fertilized
- unchopped and fertilized

Control areas were also established in undisturbed sagebrush adjacent to each of the treatment areas.

Twelve permanent vegetation transects were established (four in each treated area and two in each control area). Density of shrub species, percent cover of shrub species, and percent cover of herbaceous species were estimated within eight plots on each transect. These parameters are estimated at the end of each subsequent growing season.

3. Results

Significantly higher cover estimates and greater densities, as indicated by t-tests, were noted on corridors oriented parallel to the prevailing winds than on corridors oriented perpendicular to the wind (Appendix 6-4.2). Additional analyses using three-way ANOVA's showed that the corridors oriented parallel to the wind had significantly higher cover on fertilized areas (ammonium nitrate applied at 120 pounds per acre) than on areas which received no fertilizer (Table 6-62). Significantly higher densities were recorded on the areas which had been rotochopped as compared to those which were not chopped. No significant differences in cover or density, as based on the treatments tested, were noted on the study site oriented perpendicular to the wind. Assessments in subsequent years will be necessary before definitive trends in cover and density can be identified.

Table 6-62. Results of Three-way ANOVA's For Density and Arcsine Transformed Cover Estimates on Mule Deer Habitat Modification Study Areas[1/]

Corridor Orientation	Source of Variation															
	Fertilizer		Seeding		Chopping		Fertilizer x Seeding		Fertilizer x Chopping		Seeding x Chopping		Fertilizer x Seeding x Chopping			
	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]	F	PR>F [2/]		
Parallel to Wind																
Density	2.01	0.1590	0.49	0.4867	5.21**	0.0243	...	...	0.33	0.5696	...	...	...	...		
Cover	8.84**	0.0033	0.92	0.3388	1.19	0.2770	...	...	0.04	0.8456	...	...	...	...		
Perpendicular to Wind																
Density	0.77	0.3825	...	...	0.84	0.3606	...	...	0.29	0.5902	...	...	...	...		
Cover	1.55	0.2147	...	...	0.12	0.7263	...	...	0.13	0.7193	...	...	...	...		

** Significant at $\alpha = 0.025$

... Indicate insufficient data for completion of ANOVA.

[1/] Complete analyses are presented in Appendix 6-4.2.

[2/] Represents the significance probability (α) associated with F.

6.5 SHRUB GROWTH ENHANCEMENT ON A SIMULATED MINE SITE AND/OR DISPOSAL PILE BENCH

1. Objectives

Reclamation of areas disturbed by Tract C-a activities will be accomplished according to a state and federally approved reclamation plan. Reclamation techniques implemented by RBOSC are expected to culminate in adequate habitat for livestock and wildlife. However, any additional steps which might reduce the amount of time necessary to establish such habitat are desirable. Shrub growth enhancement through water harvesting techniques is an example of such a step.

In the semiarid environment of the Piceance Basin, increased shrub growth may be achieved by augmenting soil moisture via water harvesting techniques. Water harvesting is a technique designed to conserve and more efficiently utilize normal runoff by concentrating runoff from a large area into a smaller area.

To test the influence of increased moisture on shrub growth for wildlife cover, water harvesting techniques are being incorporated into a simulated mine site/disposal pile bench on a south-facing slope within Box Elder Gulch on Tract C-a. To reduce the potential for soil erosion, benches will be required on large slopes resulting from Tract C-a mining and/or disposal activities.

2. Methods

The design of the simulated mine site/disposal pile bench is presented in Figures 6-8 and 6-9. Water from accumulated snowpack, and runoff from snow melt and rainfall should concentrate along the two rows of shrubs on the 6:1 bench slope. Increased moisture should also be available to the shrubs in the water bar below the bench. The row of shrubs on the 3:1 slope between the bench and the lower water bar serves as a control, where shrub growth without increased moisture will be monitored.

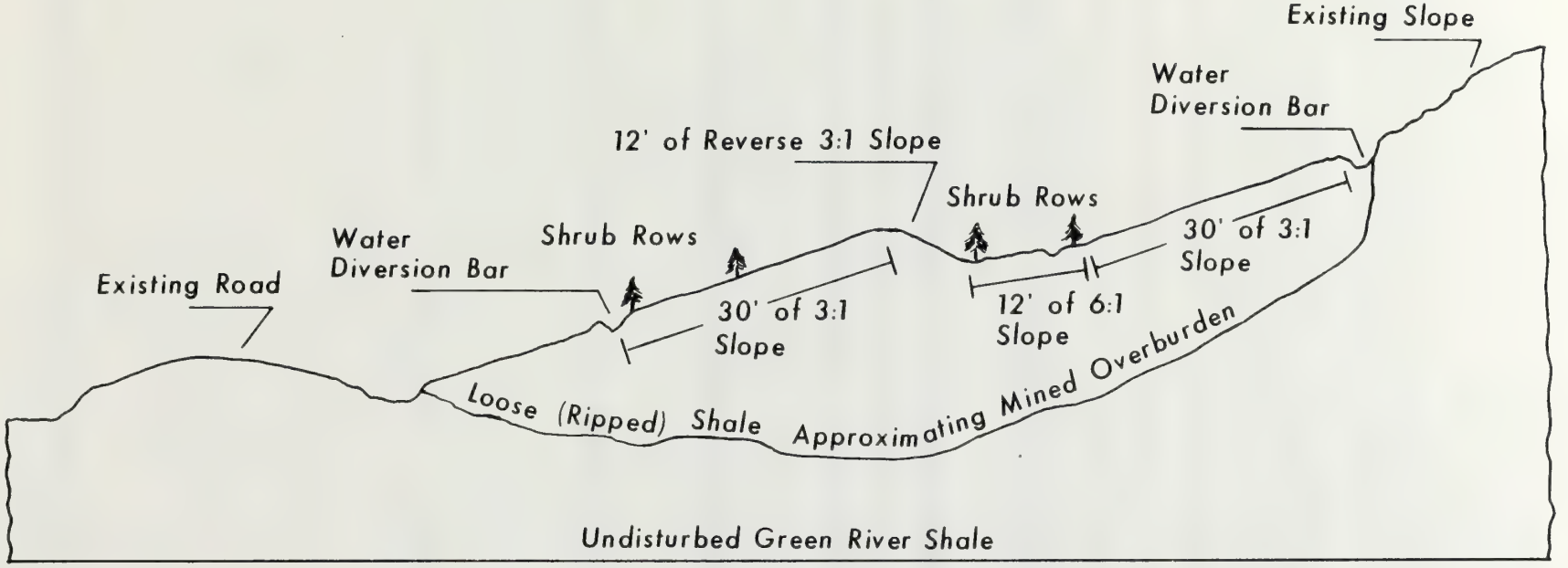


Figure 6-8 Cross Section of Simulated Mine Bench for Testing of Shrub Growth through Water Harvesting.

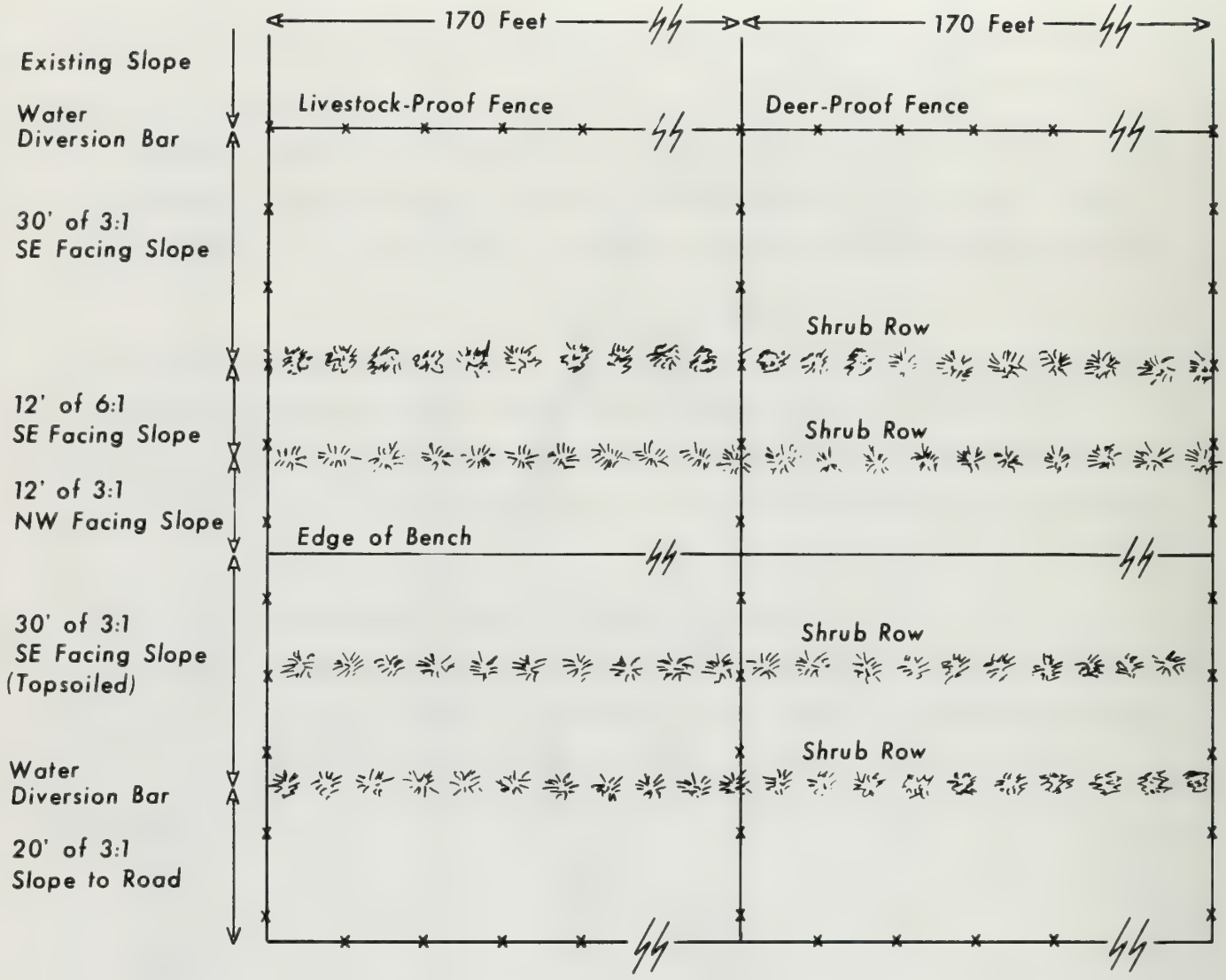


Figure 6-9. Aerial View of Simulated Mine Bench for Testing Enhancement of Shrub Growth through Water Harvesting.

Six of the seven shrub species planted in the test area are not normally used as food by deer: fourwing saltbush (Atriplex canescens), New Mexico foresteria (Foresteria neomexicana), Apache plume (Fallugia paradoxa), New Mexico black locust (Robinea neomexicana), old man wormwood (Artemisia abrotanum), and Skunkbrush sumac (Rhus trilobata). Serviceberry (Amelanchier alnifolia), a choice deer food, was included to test the effect of deer browsing pressure on shrub growth. One-half of the test will be fenced to exclude deer and cattle, and the other half will be fenced to exclude cattle but allow deer entry. All shrub species will be planted as tublings in May of 1982. Shrubs will be watered at the time of planting and irrigated as necessary during the first summer to ensure establishment; if necessary, one-half of all shrub rows on the bench and in the waterbar will be irrigated for the following two summers, to test the effect of irrigation on shrub growth. All areas between shrub rows will be planted with the RBOSC seed mixture illustrated on Table 6-63.

In order to test the effectiveness of the water harvesting technique, moisture content will be measured periodically within the soil profiles on control and treatment portions of the simulated bench. Permanently placed soil access tubes will allow for repeated soil moisture determinations at the same locations using a Troxler Soil Moisture Probe. These data, as well as assessments of plant growth, will be reported in subsequent environmental monitoring reports.

Table 6-63. Seed Mixture Used in Final Reclamation by RBOSC

Plant Species	Seeding Rate (lb PLS/acre)
Pubescent Wheatgrass (Agropyron trichophorum)	2.5
Western Wheatgrass (Agropyron smithii)	3.5
Streambank Wheatgrass (Agropyron riparium	2.0
Indian Ricegrass (Oryzopsis hymenoides)	1.5
Green Needlegrass (Stipa viridula)	1.5
Smooth Brome (Bromus inermis)	1.5
Cicer Milkvetch (Astragalus cicer)	1.5
Yellow Sweetclover (Melilotus officinalis)	0.75
Lewis Flax (Linum lewisii)	1.0
Winterfat (Ceratoides lanata)	1.0
Fourwing Saltbush (Atriplex canescens)	1.0
Bitterbrush (Purshia tridentata)	1.0
TOTAL	18.75

6.6 RANGE EXCLOSURE

1. Objectives

Tract C-a encompasses portions of two Bureau of Land Management (BLM) grazing allotments, the Square S and the Yellow Creek Allotment. Because grazing pressure may be affected by Tract C-a development, a range exclosure, established in 1975, is used to demonstrate and monitor vegetation responses to the exclusion of particular groups of mammalian herbivores. Information obtained from this study will serve to describe any potential impacts on the range condition of the area.

2. Methods

The range exclosure is located in the NW¼ of Section 8, T2S, R99W on Airplane Ridge and is composed of four seperate compartments (Figure 6-10). Compartment A (0.2 ha) is designed to exclude all mammalian herbivores while Compartment B (0.4 ha) is designed to keep out big game and livestock but not small mammals. Compartment C is 0.61 ha in size and is fenced to exclude domestic livestock and feral horses. Compartment D (0.61 ha) is the control and has no provision to exclude any animals. Sampling of these four compartments followed the methods described in Quarterly Progress Report 4 (RBOSP 1975).

The 1981 data were analyzed using the following one-way ANOVA to compare significant differences between compartments.

Source of Variation	Degrees of Freedom	F Test
A. Compartments	a-1	A/B
B. Error	a(n-1)	
	Total an-1	

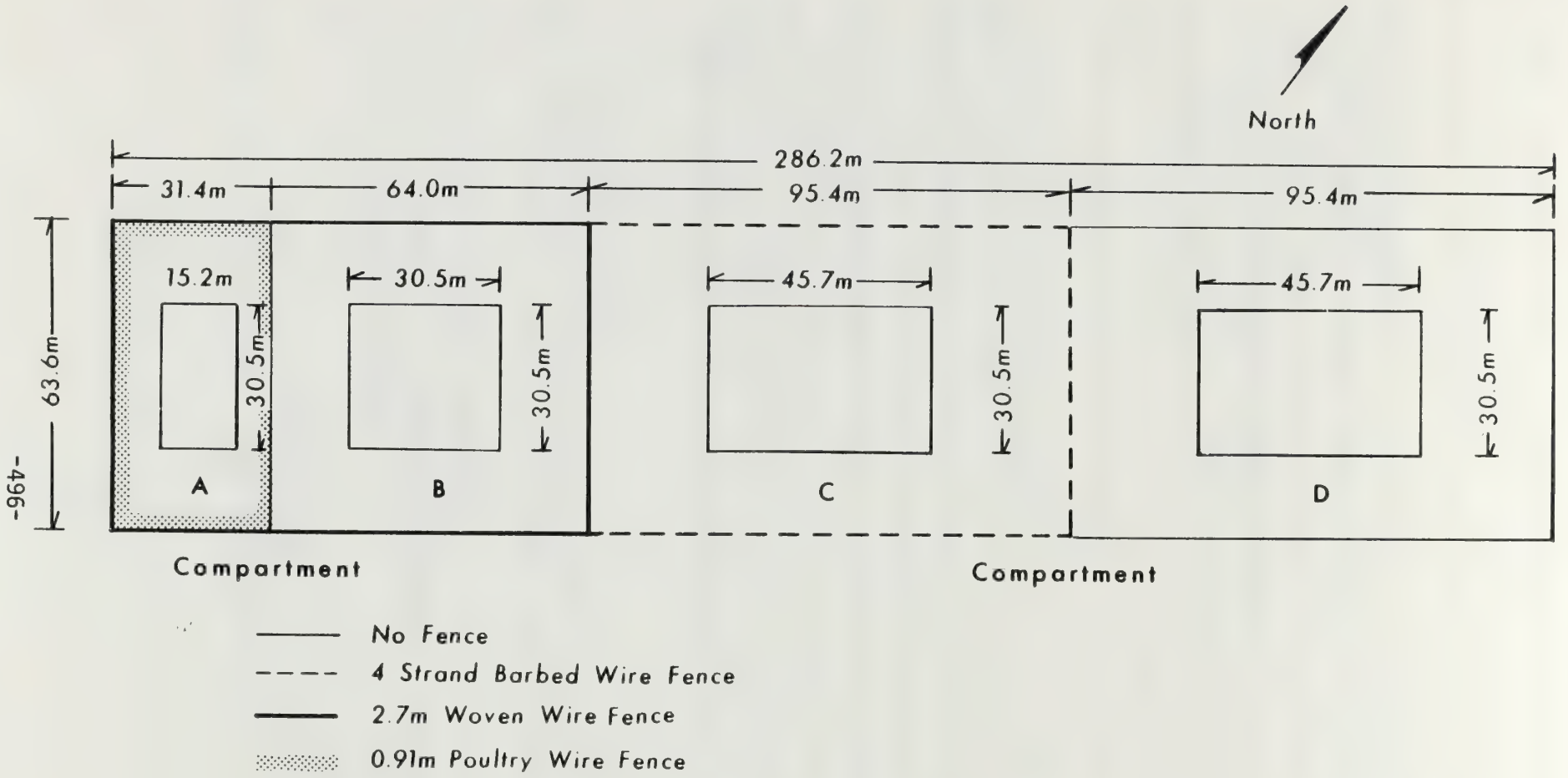


Figure 6-10. Plot Design for Range Exclosure, Tract C-a.

3. Results and Discussions

Sampling of the grass-forb stratum for cover and biomass was accomplished from June 23 to July 6, 1981. These data are summarized on Table 6-64 and included in their entirety in Appendix 6-6.1.

Total herbaceous cover was comparable between the four compartments, ranging from 4.80 to 9.17 percent (Table 6-64). The grass species encountered, through varied among compartments, accounted for most of the total herbaceous cover. The non-herbaceous components assessed for coverage consisted principally of duff and rock.

Compartment A had total herbaceous coverage of 6.92 percent (Table 6-64). The predominant grasses were the bluegrass (Poa) and wheatgrass (Agropyron) species, which together made up 72 percent of the grass coverage. Forbs, primarily lobeleaf groundsel (Senecio multilobatus), were responsible for the remaining herbaceous cover. Most of the compartment coverage was made up of duff (42.04 percent) and rock (34.08 percent).

Total herbaceous coverage for Compartment B was the highest of any compartment (9.17 percent) (Table 6-64). As in Compartment A, the grass species were responsible for the majority (96 percent) of the herbaceous cover. Wheatgrass species and Indian ricegrass (Oryzopsis hymenoides) were the primary grass species encountered. Total forb cover was 0.39 percent, consisting primarily of lobeleaf groundsel. Coverage totalling 87.51 percent comprised non-herbaceous components, primarily rock, soil, and duff.

Coverage of herbaceous species was 5.64 percent for Compartment C (Table 6-64). Grasses were responsible for 94 percent of this cover; forb species constituted 6 percent. The dominant grasses in Compartment C were identical to those in Compartment B; northern sweetvetch (Hedysarum boreale) was the dominant forb. The non-herbaceous components, primarily duff, rock, and soil, accounted for 87.14 percent coverage in this compartment.

The lowest herbaceous coverage of any compartment (4.80 percent) was encountered in Compartment D. Of this total, grass species, primarily wheatgrasses, were responsible for 91 percent. Scarlet globemallow (Sphaeralcea coccinea),

responsible for 59 percent of the forb coverage, was the dominant forb. Surface components, similar to those in the previous two compartments, accounted for 92.59 percent of the total compartmental coverage.

Analyses comparing herbaceous coverage between compartments exhibited no significant differences (Table 6-65).

Average cover over the four compartments (6.6 percent) was lower than the 14.8 percent herbaceous cover encountered along the five transects of phytosociological sampling Area 5 (RBOSC 1980). Area 5 was used for comparison purposes since it is in the same general vicinity as the range exclosure. Although it is unclear why coverage for Area 5 is higher, a possible reason 13.79 kg/ha. The dominant grasses were the wheatgrass species and Indian ricegrass, which were responsible for 94 percent of the total grass biomass. Lobeleaf groundsel, the predominant forb species, accounted for 63 percent of the total forb production.

Production in Compartment C (146.72 kg/ha) was the second highest of the four compartments (Table 6-64). Grasses, specifically wheatgrass and Indian ricegrass species, accounted for 96 percent of the total, or 140.32 kg/ha. Northern sweetvetch and tumblemustard (Sisymbrium linifolium) were responsible for 80 percent of the 6.40 kg/ha total forb production.

Compartment D had the lowest production of the four compartments, 89.13 kg/ha (Table 6-64). As in the other compartments, grass production was responsible for the majority of the herbaceous biomass. The wheatgrass species and Indian ricegrass accounted for 60.49 kg/ha, 75 percent of the total grass production of 80.76 kg/ha. Forb species, primarily scarlet globemallow, contributed production of 8.37 kg/ha.

The statistical comparison among compartments for 1981 biomass data exhibited no significant differences for either grasses or forbs (Table 6-65).

Production during 1981 for all four compartments is lower than that encountered in 1975 (RBOSP 1976). Total herbaceous production was 89.99 kg/ha versus 101.93 for Compartment A, 197.31 versus 491.10 kg/ha for B, 146.72

Table 6-64. Coverage (%) of Herbaceous Species and Non-herbaceous Components, and Biomass (kg/ha) of Herbaceous Species Within Four Areas of the RBOSC Range Exclosure, Tract C-a

Species	Compartment A		Compartment B		Compartment C		Compartment D	
	Cover	Biomas	Cover	Biomass	Cover	Biomass	Cover	Biomass
Grasses								
Agropyron species	1.00	15.14	4.68	107.24	2.63	66.14	2.08	46.48
Bromus tectorum	0.50	1.58			0.06	1.43	0.80	9.72
Carex species	0.20	0.68	0.15	2.49				
Hordeum jubatum					0.08	1.73	0.09	1.96
Koeleria cristata							0.02	1.05
Oryzopsis hymenoides	0.80	31.00	3.21	65.09	1.89	59.50	0.75	14.01
Poa species	3.82	35.48	0.74	8.70	0.51	8.96	0.40	3.62
Sitanion hystrix	0.42	4.52			0.13	2.56	0.25	3.92
Subtotal	6.74	88.40	8.78	183.52	5.30	140.32	4.39	80.76
Forbs								
Astragalus diversifolius			0.04	0.57				
Astragalus purshii							0.05	1.28
Crucifer species							0.02	0.68
Haplopappus nuttallii			0.03	1.13				
Hedysarum boreale					0.18	3.39		
Ipomopsis aggregata			0.04	0.57			0.01	0.15
Lepidium perfoliatum	0.02	0.23						
Penstemon species					0.01	0.23		
Physaria floribunda	0.02	0.68	0.09	1.58	0.04	0.45	0.02	0.68
Senecio multilobatus	0.14	0.68	0.13	8.70	0.02	0.45		
Sisymbrium linifolium			0.02	0.11	0.08	1.73	0.06	1.21
Sphaeralcea coccinea							0.24	4.14
Trifolium gymnocarpon			0.02	0.34	0.01	0.15		
Unknown composite			0.02	0.79			0.01	0.23
Subtotal	0.18	1.59	0.39	13.79	0.34	6.40	0.41	8.37
Total Herbaceous Coverage	6.92	89.99	9.17	197.31	5.64	146.72	4.80	89.13
Non-herbaceous Components								
Soil	16.70		30.49		24.47		22.33	
Duff	42.04		24.03		32.84		30.50	
Moss or Lichen			0.11		0.14		0.03	
Rock	34.08		32.88		29.69		39.73	
Total Non-Herbaceous Coverage	92.82		87.51		87.14		92.59	

Table 6-65. Summary of One-Way ANOVA Results Comparing Grass and Forb Coverage (first listing) and Biomass (second listing) Between Compartments of the Range Exclosure, Tract C-a[1/]

Growth Form	Source of Variation Compartments	
	F Value	PR>F[2/]
Grasses	0.94	0.4436
Forbs	0.12	0.9500
Grasses	0.99	0.4199
Forbs	0.63	0.6050

[1/] Complete analyses are presented in Appendix 6-6.2.
[2/] Represents the significance probability (α) associated with F.

is that the range exclosure is in an ecotonal area between true pinyon-juniper and true sagebrush habitat types, resulting in a reduced total herbaceous coverage.

Total herbaceous biomass averaged 130.79 kg/ha over the four range exclosure compartments, ranging from 89.13 to 197.13 kg/ha (Table 6-64). As expected, the compartment with the lowest coverage (D) had the lowest biomass and compartment B, with the highest coverage, had the highest biomass.

Compartment A had total biomass of 89.99 kg/ha with grass species accounting for 98 percent of the total. The bluegrass species and Indian ricegrass were responsible for the majority of the 88.4 kg/ha total grass biomass. Two forbs, lobeleaf groundsel and twinpod (Physaria floribunda), constituted most of the 1.59 kg/ha forb biomass.

Total herbaceous biomass amounted to 197.31 kg/ha for Compartment B (Table 6-64). Grass species accounted for 183.52 kg/ha, while forb species accounted for

versus 363.04 kg/ha for C, and 89.13 versus 286.71 kg/ha for Compartment D (1981 versus 1975, respectively). It is unclear why production for herbaceous species was markedly lower in 1981 than in 1975. At least an equal or increased production in compartments A through C was anticipated since mammalian herbivores, for the most part, have been excluded.

Production data from the range exclosure were also compared to data from the pinyon-juniper range production transects (Section 3.1D). Average herbaceous production for the four compartments (130.79 kg/ha) was higher than the average production over the 16 pinyon-juniper transects (106.6 kg/ha) sampled during 1981.

6.7 SUPPLEMENTARY SULFUR DIOXIDE MONITORING PROGRAM

Operational difficulties during the MIS Retort One burn in 1981 necessitated a shutdown of the retort off-gas scrubber during September and October. During this shutdown, retort off-gases could not be scrubbed, so they were combined with natural gas and "flared". The agencies responsible for administering RBOSC's air quality permits stipulated that a supplementary sulfur dioxide monitoring program be designed and implemented during the flare period as a condition for allowing the flaring. This section summarizes the results of that monitoring program.

The supplementary sulfur dioxide monitoring program employed two types of sampling: continuous sulfur dioxide monitoring at RBOSC Air Quality Monitoring Sites 1 and 3 and bag sampling at various points on and around Tract C-a. Bag sampling locations were concentrated in the vicinity of Site 1 and in Corral Gulch near the western boundary of Tract C-a, the area where highest emission concentrations would be expected during periods of stable upvalley air flow.

Table 6-66 gives the highest sulfur dioxide concentrations found for each sampling day during the monitoring period (September 18 - October 21), both at Site 1 and at the locations where bag samples were taken. The bag sampling program was initiated October 1 after acquisition of the necessary equipment and conditioning of the bags had been completed.

Sulfur dioxide concentrations are not listed in Table 6-66 for many of the days during this period, because concentrations are given only when they were above background levels. In addition, the bag sampling was done only when atmospheric conditions would be expected to produce relatively high ground level concentrations. The meteorology during this period was generally conducive to good dispersion (and hence low ground level concentrations of sulfur dioxide), with relatively high winds and above average precipitation. Precipitation was recorded on 11 days of this 34-day period. More precipitation was measured during October 1981 than during the three previous Octobers combined.

Table 6-66. Results of Supplemental Sulfur Dioxide Monitoring Program (Data Presented Only When Concentrations are Significantly Above Background Level)

Bag Sampling Program

Date	Highest Monitored Concentrations (ppm)	Highest Monitored Concentrations ($\mu g/m^3$)	Time	Location
10/01/81	0.120	(260)	11:25 AM	2.5 km SW of flare stack, up Corral Gulch
10/06/81	0.021	(46)	11:04 AM	3 km WNW of flare stack, near Site 1
10/07/81	0.022	(48)	10:30 AM	2.5 km SW of flare stack, up Corral Gulch
10/13/81	0.012	(26)	8:52 AM	3 km WNW of flare stack, near Site 1
10/19/81	0.039	(85)	9:30 AM	2.5 km SW of flare stack, up Corral Gulch
10/21/81	0.022	(48)	10:25 AM	3 km WNW of flare stack, near Site 1

Continuous Monitoring Program (Site One)

Date	Highest Monitored Concentrations (ppm)	Highest Monitored Concentrations ($\mu g/m^3$)	Time
9/26/81	0.020	(43)	7:45 AM
9/27/81	0.013	(28)	8:45 AM
9/30/81	0.039	(85)	10:20 AM
10/01/81	0.048	(104)	3:55 AM
10/06/81	0.032	(69)	10:00 AM
10/13/81	0.022	(48)	8:45 AM
10/15/81	0.025	(54)	9:40 AM
10/17/81	0.013	(28)	8:40 AM
10/18/81	0.022	(48)	8:20 AM
10/19/81	0.054	(117)	9:40 AM
10/21/81	0.020	(43)	10:35 AM

The highest instantaneous sulfur dioxide concentration recorded during the entire program (0.12 ppm or 260 $\mu g/m^3$) was measured in Corral Gulch on October 1 under conditions of sunny skies and easterly winds, which transported the plume westward up Corral Gulch toward higher ground. It is worth noting that this concentration was measured at 11:25 a.m. and was a very short term condition--measurements at the same location taken at 9:00 a.m. (when fumigation might be expected) and at 10:30 a.m. showed concentrations of 15 and 40 percent of the 11:25 a.m. peak, respectively. Shortly after 11:35 a.m., the wind shifted to the west, and the SO_2 concentrations fell to levels near background. The highest concentrations found by the continuous monitoring of Site 1 (0.048 ppm) also occurred on October 1, but at 3:55 a.m. These readings indicate that the plume impacts show large spatial and temporal variabilities.

The second highest SO_2 concentration, 0.054 ppm, was measured on October 19 at Site 1. Measurements taken with bag samplers in Corral Gulch at the same time showed concentrations as high as 0.039 ppm, suggesting that the plume is well dispersed over the rough terrain rather than maintained as a discrete entity.

The data acquisition system at Site 1 computes five-minutes averages from the continuous SO_2 monitoring, which permits analysis of temporal variability of SO_2 concentrations at that location. In general, ground level impacts are very transitory, peak concentrations occurring over very short periods. For instance, the peak five-minute average of 0.054 ppm on October 19 was accompanied by only two other five-minute averages above 0.030 ppm. Similarly, the 0.032 ppm peak on October 6 was accompanied by only three other five-minute averages above the background SO_2 level. The variability of plume behavior and transport phenomena is also evidenced by the fact that the time of the peak daily concentration at Site 1 varied between 3:55 and 10:35 am (Table 6-66).

The sulfur dioxide concentrations measured by the continuous Site 1 monitor and the bag sampling program correspond closely. On two occasions, the highest daily concentrations were found with nearly simultaneous measurements at Site 1 by both the bag samplers and the continuous monitors. On October 21

the bag samplers measured 0.022 ppm and the continuous monitors measured 0.020 ppm; on October 13, the measured concentrations were 0.012 and 0.022 ppm, respectively (Table 6-66).

In the summary, the supplemental sulfur dioxide monitoring program showed no concentrations approaching either the NAAQS or PSD Class II increments. The highest impacts were very transitory and showed a great deal of variability both in time and space, sometimes occurring in Corral Gulch and sometimes on higher ground near Site 1. The highest concentrations were found near the west boundary of the tract, with decreasing concentrations on higher ground further to the west. Elevated concentrations found simultaneously at Site 1 and in Corral Gulch suggest that the plume is widely dispersed, at least part of the time.

6.8 SUMMARY

A. Experimental Revegetation on Surface Disturbed Sites

Experimental revegetation Plot R-1, located on a northwestern exposure, had average coverage over the 16 treatment combinations of 43.1 percent for all species encountered during 1981. Planted grasses, specifically wheatgrass (Agropyron) species and, to a lesser extent, green needlegrass (Stipa viridula), accounted for 49 percent of the total R-1 average. A statistical comparison of 1981 grass coverage data between treatment combinations exhibited no significant main or interaction effect differences ($\alpha \leqq 0.05$). However, comparison of data over the five sampling years indicated that planted grass coverage was significantly higher in 1980 and 1981 than for the previous three years. The biomass of planted grasses averaged 599.1 kg/ha over the 16 treatment regimes. A comparison of 1981 biomass data exhibited no significant differences ($\alpha \leqq 0.05$) for main or interaction effects. However, when data from 1981 and 1978 were compared, the production of planted grasses was significantly higher in 1981 than in 1978.

Planted forb coverage averaged 10.5 percent over the treatment combinations and was responsible for 24 percent of the total R-1 cover. The dominant forb species were Lewis flax (Linum lewisii), yellow sweetclover (Melilotus officinalis var. Madrid), and cicer milkvetch (Astragalus cicer var. Lutana). For the 1981 data, planted forb coverage was significantly higher ($\alpha \leqq 0.05$) on the plots in Block 2 than on the other two blocks. Comparison of data over the sampling years indicated significantly higher planted forb coverage during 1980 and 1981 than in the other years. The biomass of planted forbs averaged 152.3 kg/ha over the 16 treatment regimes. The 1981 data did not exhibit any significant differences ($\alpha \leqq 0.05$) when compared using a three-way ANOVA. However, there was significantly higher forb production in 1981 than what was encountered in 1978.

The higher planted grass and forb production in 1981 when compared to 1978 is probably due to an increase in moisture over the years. Data from the rain gauges at R-1 indicate that moisture has steadily risen from 4.83 in. in 1978 to 9.38 in. in 1981.

Coverage of planted shrubs averaged 2.7 percent, which was 6 percent of the total coverage. Rabbitbrush (Chrysothamnus nauseosus and C. viscidiflorus), and winterfat (Ceratoides lanata) were the most dominant planted shrub species. There were no statistical differences ($\alpha \leq 0.05$) when the 1981 data was analyzed with a three-way ANOVA. Comparison of planted shrub coverage over sampling years exhibited significantly lower cover after one year's growth than that exhibited in subsequent years.

Experimental revegetation Plot R-2, established in 1975 on a southeasterly slope, had average cover of 30.1 percent for all species encountered during 1981. The planted grasses were responsible for 39.5 percent of this total and had average coverage of 11.9 percent. Wheatgrass species and Indian ricegrass (Oryzopsis hymenoides) were the dominant planted grasses, while green needlegrass was a common subordinate species. There were no significant differences among treatment regimes ($\alpha \leq 0.05$) when the data collected in 1981 were analyzed, but there were significant differences when the planted grass cover data was compared among years. Planted grass coverage was significantly higher in 1980 than in 1981, both of which are significantly higher than any of the other three sampling years. Average planted grass biomass was 270.5 kg/ha and was primarily made up by those grass species with the highest coverage. No significant differences among treatment regimes ($\alpha \leq 0.05$) were indicated by analyses of the 1981 biomass data. There were, however, significant differences when the data were compared among years. Production of planted grasses was significantly greater in 1981 than in 1978.

Coverage of planted forbs averaged 7.3 percent over the 16 treatment combinations and was responsible for 24.3 percent of the total R-2 coverage. The prominent forb species were Lewis flax and cicer milkvetch, with yellow sweetclover occurring as a subordinate forb. A statistical comparison of 1981 forb data exhibited no significant main or interaction effect differences ($\alpha \leq 0.05$). When data from all years were analyzed, coverage of planted forbs in 1980 and 1981 was significantly higher than in previous years. These differences in forb coverage seem to be related to a block x mulch x fertilizer interaction effect with no corresponding main effect differences. Production of the planted forbs averaged 150.1 kg/ha. Most of this production consisted of Lewis flax, cicer milkvetch, and yellow sweetclover. When the 1981 planted forb biomass data were analyzed by the

three-way ANOVA, no significant differences among treatment regimes ($\alpha \leq 0.05$) were noted. Significant differences did arise when data for 1978 and 1981 were compared. Planted forb biomass was significantly greater in 1981 than in 1978.

Planted shrub coverage accounted for 18.6 percent of the R-2 total with average cover over the different treatment combinations of 5.6 percent. The two rabbitbrush species and winterfat were the dominant planted shrub species. Based on 1981 data, no significant main or interaction effect differences were noted. However, a comparison of data over the five sampling years exhibited significantly higher coverage in 1980 and 1981 than in the previous three sampling years. These differences may be attributed to differences in the mulch treatments as well as significant block x mulch interaction effects. Plots that were hydromulched had significantly greater shrub coverage than plots with the other three mulch treatments (no mulch, crimped straw, and straw covered with netting).

The total biomass on Plot R-2 for the clipped grass and forb species averaged 492.1 kg/ha. The planted grasses were responsible for 55 percent of the total compared to 30.5 percent for the planted forbs.

A comparison between data from Plots R-1 and R-2 and data from the neighboring, undisturbed sagebrush community revealed that production on these revegetation plots exceeded that of the sagebrush plant community. Herbaceous production averaged 435.3 kg/ha during 1981 along the sagebrush production transects, compared to 831.0 kg/ha for Plot R-1 and 492.1 kg/ha for Plot R-2.

B. Experimental Revegetation on a Simulated Processed Shale Disposal Site

Coverage averaged over all treatment combinations for species present on Plot R-3 during 1981 was 37.5 percent on the treatment portion (underlain by processed shale) and 38.4 percent on the control portion (not underlain by processed shale). The highest coverage on the treatment portion was recorded

on the hay mulch/low seeding combination, while the lowest coverage was found on the no mulch/low seeding combination. On the control portion, the highest coverage was found on the hay mulch/high seeding combination; the lowest coverage was obtained on the no mulch/low seeding combination.

The prominent planted grass species encountered on both the control and treatment portions of Plot R-3 were wheatgrass species and Indian ricegrass. The most prevalent invading grass species were cheatgrass (Bromus tectorum) and crested wheatgrass (Agropyron cristatum). Coverage of all planted grasses averaged 21.4 and 24.0 percent on control and treatment portions, respectively. A comparison of 1981 coverage data for all planted and invaded grasses indicated that significant differences ($\alpha \leqq 0.05$ and 0.025 for plant and invaded species, respectively) exist among the various seeding regimes, but not among fertilizer treatments or between shale-no shale substrates. Planted grass cover was significantly higher on areas seeded at 28 kg/ha than those seeded at 17 kg/ha. Invading grasses exhibited significantly higher coverage on plots seeded at the lowest rate (17 kg/ha) than plots seeded at either the medium (22 kg/ha) or the high (28 kg/ha) seeding rate.

Planted grass coverage on Plot R-3 was highest during 1979 and has decreased slightly since that time. The decreased coverage noted during 1980 and 1981 is a result of sampling aboveground biomass during the 1979 season via destructive techniques (coverage estimates in subsequent years were made on the same quadrats upon which biomass was measured in 1979). Data for 1980 and 1981 indicate that planted grasses recover quickly from the impact of destructive sampling, which simulates heavy grazing pressure. However, the coverage of planted grasses the second year after destructive sampling is still significantly lower ($\alpha \leqq 0.05$) than that recorded in 1979. Furthermore, concomitant with reduced coverage of planted species, coverage of invaded grasses was significantly higher ($\alpha \leqq 0.05$) in 1980 than during any other sample period.

Planted forb coverage values averaged over all treatment combinations within control and treatment portions of Plot R-3 were 8.9 and 5.7 percent, respectively. The highest coverage of planted forbs on both the control and treatment portions of Plot R-3 was recorded on areas which were hydromulched and seeded

at 17 kg/ha (the lowest rate). Cicer milkvetch was the dominant forb throughout Plot R-3; however, Lewis flax and yellow sweetclover were subordinate forbs commonly occurring on both the control and treatment portions of the site. A comparison of 1981 coverage data for all planted and invaded grasses indicated that there were no significant differences ($\alpha \leq 0.05$) in coverage based on any of the treatments tested.

Planted forb coverage has increased subsequent to clipping quadrats for biomass determinations in 1979 (3.5 percent in 1979; 7.3 percent in 1981). This increase may be related to decreased competition from grass species. Statistical comparisons of forb coverage data among years indicate that 1981 coverage, though similar to that for 1980, was significantly higher ($\alpha \leq 0.05$) than that recorded for 1977, 1978, or 1979.

Planted shrub coverage averaged 4.2 and 4.6 percent on control and treatment portions of R-3, respectively. The greatest planted shrub coverage on the control portions was found on plots which were seeded at 22 kg/ha and hydromulched, whereas the seeding rate of 28 kg/ha followed by hydromulching resulted in the highest planted shrub coverage on the treatment portion of the study site. Winterfat and fourwing saltbush (Atriplex canescens) were the dominant planted shrub species. Broom snakeweed (Gutierrezia sarothrae) was the most common invading shrub species encountered on both the control and treatment areas. A comparison of total shrub coverage among all treatment combinations for 1981 showed no significant differences ($\alpha \leq 0.05$) based on substrate, mulch, or seeding rate treatments.

Coverage of planted shrub species on the quadrats sampled declined from a high of 16.7 percent in 1979 to 4.4 percent in 1981. Coverage recorded during 1981, 1980, 1978, and 1977 is significantly lower ($\alpha \leq 0.05$) than that noted for 1979. Because shrub species are not expected to readily produce growth from rootstocks as do many grasses and forbs, the planted shrubs on Plot R-3 did not recover from destructive sampling conducted in 1979 as well as the grass and forb species.

No significant differences ($\alpha \leq 0.05$) between electrical conductivity (EC) in soils from control and treatment portions of the study site were noted during 1981. As expected, EC increased with depth in the reconstructed soil profiles

on both the control and treatment sides of R-3, probably as a result of the increased amount of unweathered parent material. Electrical conductivity data suggest that the rubblized overburden materials within the reconstructed soil profile are continuing to prevent capillary migration of dissolved salts from the processed shale into the surface growth medium.

C. Experimental Revegetation Greenhouse Studies

Greenhouse studies were undertaken to assess the revegetation potential of Lurgi processed shale. The objectives of the studies were (1) to determine the concentrations of boron (B), molybdenum (Mo), fluorine (F), arsenic (As) and selenium (Se) in plants grown in Lurgi processed shale, as well as in various depths of topsoil and subsoil over the Lurgi processed shale; (2) to determine plant growth and response in various growth mediums, using techniques including biomass measurements of roots and shoots; (3) to investigate the suitability of Lurgi processed shale as a medium for seed germination; and (4) to assess the potential of stockpiled Tract C-a topsoils to infect roots with beneficial vesicular-arbuscular mycorrhizal fungi.

Five plant species (five replicates per species) were grown for six months within 11 variations of topsoil, subsoil and/or capillary barrier depths over Lurgi processed shale. The treatments, including two topsoil controls and one shale only treatment, were as follows:

1. 15 cm topsoil (control)
2. 30 cm topsoil (control)
3. 15 cm shale
4. 15 cm topsoil, 15 cm shale
5. 15 cm topsoil, 15 cm subsoil barrier, 15 cm shale
6. 15 cm topsoil, 30 cm subsoil barrier, 15 cm shale
7. 30 cm topsoil, 15 cm shale
8. 30 cm topsoil, 15 cm subsoil barrier, 15 cm shale
9. 30 cm topsoil, 30 cm subsoil barrier, 15 cm shale
10. 15 cm topsoil, 15 cm gravel barrier, 15 cm shale
11. 15 cm topsoil, 30 cm gravel barrier, 15 cm shale

The differential response of plants grown in the various treatments showed that growth in 30 cm of topsoil was superior to that in only 15 cm of topsoil. Adding an additional layer of subsoil below the topsoil improved plant growth. The use of pea gravel as a capillary barrier did not result in significantly better growth than that recorded for the 15 cm topsoil control ($\alpha \leqq 0.05$). The Lurgi shale underlying the various topsoil/subsoil growth mediums did not appear to hinder plant growth. Average aboveground production was nearly indentical among the five species tested. Furthermore, there was no significant difference in root biomass among the treatments.

The migration of boron, molybdenum, and fluoride from the processed shale into the overlying soils did not appear to occur under the conditions of this study. In fact, there appeared to be losses of the water soluble B, Mo and F from the topsoil/subsoil growth mediums due to leaching. A reduction in electrical conductivity indicated that leaching of salts from the surface growth mediums also occurred. The Lurgi process appears to cause a reduction in the availability of B and Mo in comparison to the TOSCO and U.S. Bureau of Mines processes. The uptake of B by plants was not significantly different ($\alpha \leqq 0.05$) among any of the treatments and topsoil controls. The B levels recorded were well within the tolerable levels for plant growth and animal uptake. Molybdenum also occurred in relatively low values in plants grown under all treatment conditions. However, the Mo content was significantly higher ($\alpha \leqq 0.05$) in plants grown in the shale-only as well as 15 cm topsoil over shale treatments when compared with topsoil controls (15 and 30 cm topsoil only). The fluorine content of plants grown in straight Lurgi processed shale reached high levels. The fluorine content dropped drastically, however, when only 15 cm of topsoil was placed over the shale. Similarly, the Se level in plants grown in straight shale was very high, but was reduced greatly with an application of 15 cm of topsoil over the shale. The low levels of arsenic measured in all plants and treatment profiles analyzed appear to offer no potential hazards to plant growth or for grazing animals.

Seed germination for the 12 species tested was very poor in or on Lurgi processed shale. The three germination treatments (surface, 1 cm and 2.5 cm)

were not significantly different; however, all three exhibited significantly lower ($\alpha \leq 0.05$) germination than that recorded on topsoil controls.

Under greenhouse conditions, the five test species grown in the topsoil/subsoil surface growth media from Tract C-a were found to be naturally inoculated with vesicular-arbuscular mycorrhizal fungi (VAM). Underlying shales and/or a capillary barrier had no discernible impact on VAM propagation in the Tract C-a topsoils.

D. Toxicology

Extensive toxicological and industrial hygiene studies are being conducted by the U.S. Department of Energy (DOE) Oil Shale Task Force and RBOSC on the products and by-products of MIS and Lurgi oil shale retorting. These studies are designed to characterize the physical and chemical properties, to determine biological activities, and to assess potential worker exposure and environmental hazards of oil shale process materials.

Preliminary results of the DOE research on MIS Retort Zero indicate that the sour water was more dilute than process waters for other in situ retorts. The crude shale oil, on the other hand, contained more sulfur than other shale oils. Analyses of the off-gases indicated that mercury and nitrogen oxide concentrations generally increased as the burn progressed. Testing of stack particulates demonstrate that most of the particulate organic material consisted of polycyclic aromatic hydrocarbons. Analyses of soil samples showed that there are significant differences in natural background concentrations of mercury among different soil types.

Sampling of hydrogen sulfide and dust conducted during the Retort Zero burn indicated that the Threshold Limit Values for 8-hr exposures to hydrogen sulfide and dust were not exceeded. Additional data on the DOE toxicological and other DOE-sponsored studies will be available in the near future.

Screening tests were conducted to determine the toxicity and mutagenicity of various MIS generated materials. Toxicity tests using a bioluminescent strain of bacteria and the test organisms indicated some toxicity associated

with certain MIS sour waters. Both the Ames and sister chromatid exchange tests of MIS shale oil yielded positive results for mutagenic activity.

RBOSC-sponsored toxicology tests conducted by IIT Research Institute are presently underway for both MIS and Lurgi-generated materials. The battery of tests include acute toxicity tests, tests to evaluate dermal and ocular irritation, and genetic assays such as the Ames Test, forward mutation assay and dermal cytogenetics tests. These tests are scheduled to be completed in 1982.

E. Run-Of-Mine Lysimeter

RBOSC, in cooperation with the EPA, the USGS, and the DOE Task Force, is conducting leaching studies on stockpiled run-of-mine ore in order to determine the chemical characteristics of leachate generated from raw shale in the field and to compare these results with those from laboratory tests on the same materials. This comparison is being conducted to determine the importance of such factors as percolation rates (residence time), wetting and drying cycles, and other weathering factors on leachate quality.

The field lysimeter tests were initiated in mid-June, 1980. The results of the tests, both leachate volumes and chemical analyses, were published in a First Annual Progress Report for the period April 1, 1980 - May 31, 1981, by Dr. David McWhorter (1981). A summary of this report was included in MDP 8. Since May 3, 1981, additional samples have been collected and analyzed. The lysimeters have been monitored only for volume (no sampling) since November 1981. Publication of a second annual progress report is expected in the Spring of 1982. The relevant portions of the forthcoming report will be included in the next MDP monitoring report.

F. Mule Deer Habitat Modification

During RBOSC's commercial operation, disturbances of the land will result in the loss of forage for wildlife, primarily mule deer. One means of mitigating these losses is to increase the mule deer carrying capacity of undisturbed areas to maintain the overall carrying capacity at, or near, predevelopment levels. RBOSC initiated an experiment in 1980 to determine the feasibility

of producing such increases in carrying capacity using habitat modification techniques.

The habitat modification experiment was designed to evaluate the effects of several factors critical to increasing deer carrying capacity: (1) snow depth, (2) moisture availability during the growing season, (3) selective brush removal, (4) quality forage, and (5) fertilization. Four 5-m corridors were chopped in each of two treatment areas, such that a differential accumulation of snow should occur between the two areas, thereby enabling an evaluation of the effects of such accumulation on forage production and utilization as well as deer movement. Half of each treatment area was seeded and fertilized with ammonium nitrate. Eight treatment regimes were thereby established. Control areas were also established in undisturbed sagebrush adjacent to each of the treatment areas.

Twelve permanent vegetation transects were established (four in each treatment area and two in each control area). Density of shrub species, percent cover of shrub species, and percent cover of herbaceous species were estimated within eight plots on each transect.

Significantly higher cover estimates and greater densities, as indicated by t-tests, were noted on corridors oriented parallel to the prevailing winds than on corridors oriented perpendicular to the wind. Additional analyses using three-way ANOVA's showed that the corridors oriented parallel to the wind had significantly higher cover on fertilized areas (ammonium nitrate applied at 120 pounds per acre) than on areas which received no fertilizer. Significantly higher densities were recorded on the areas which had been rotochopped as compared to those which were not chopped. No significant differences in cover or density, as based on the treatments tested, were noted on the study site oriented perpendicular to the wind. Assessments in subsequent years will be necessary before definitive trends in cover and density can be identified.

G. Shrub Growth Enhancement on a Simulated Mine Site and/or Disposal Pile Bench

A simulated mine site/disposal pile bench was constructed on Tract C-a in early 1982. The simulated bench is designed principally to evaluate the effects of water harvesting techniques on shrub growth. In addition, the effects of artificial irrigation, topsoil depth, and grazing are to be evaluated. The bench is designed to concentrate available moisture in certain areas, using water bars and variations in slope. Various combinations of fencing and topsoil applications will also be tested. Shrubs will be planted in each of the resulting treatment areas in the spring of 1982. Shrub growth will be evaluated on a yearly basis, to identify any effects of the various treatments on shrub growth. The success of the water harvesting techniques will be evaluated by periodic measurements of soil moisture content at fixed locations. The results of these evaluations will be included in subsequent MDP Environmental Monitoring Reports.

H. Range Exclosure

The range exclosure, located on Airplane Ridge near the western boundary of Tract C-a, had an average cover of 6.6 percent for the four compartments. Compartment B had a high herbaceous coverage of 9.17 percent, whereas the lowest herbaceous species coverage values were 6.92 and 5.64 percent, on compartments A and C, respectively. Grasses, primarily the wheatgrass, bluegrass (Poa), and Indian ricegrass species, accounted for the majority of the coverage on the four compartments. The predominant forbs were lobeleaf groundsel (Senecio multilobatus) for compartments A and B, northern sweetvetch (Hedysarum boreale) for Area C, and scarlet globemallow (Sphaeralcea coccinea) for compartment D. The statistical analyses comparing herbaceous coverage between compartments exhibited no significant differences ($\alpha \leq 0.05$).

Average biomass for the range exclosure was 130.79 kg/ha. Production values were 89.99, 197.31, 146.72, and 89.13 kg/ha for compartments A, B, C, and D, respectively. The predominant grass and forb species responsible for most of the herbaceous coverage also made up most of the herbaceous biomass. The

statistical comparison for 1981 biomass data between the four compartments exhibited no significant differences ($\alpha \leq 0.05$) for either grasses or forbs.

I. Supplementary Sulfur Dioxide Monitoring Program

The supplemental sulfur dioxide monitoring program showed no concentrations approaching either the NAAQS or PSD Class II increments. The highest impacts were very transitory and showed a great deal of variability both in time and space, sometimes occurring in Corral Gulch and sometimes on higher ground near Site 1. The highest concentrations were found near the west boundary of the tract, with decreasing concentrations on higher ground further to the west. Elevated concentrations found simultaneously at Site 1 and in Corral Gulch suggest that the plume is widely dispersed at least part of the time.

LITERATURE CITED

Gough et al. 1979. Element concentrations toxic to plants, animals and man. Geological Survey Bulletin 1466. USGPO, Washington. 80 pp.

McWhorter, D.B. Field leaching study of raw mined oil shale; first annual progress report; reporting period 4/1/80-5/31/81. Colorado State University.

Ostler, W.K. 1981. Plant growth parameters in relation to reclamation of Lurgi processed oil shale and topsoil. Native Plants, Inc., Salt Lake. Research report prepared for the Rio Blanco Oil Shale Co., Denver.

Rio Blanco Oil Shale Project. 1975. Quarterly progress report 4. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1976. Quarterly progress report 5. Gulf Oil Corp. and Standard Oil Co. (Indiana).

Rio Blanco Oil Shale Company. 1977. Revegetation program 1976 annual report. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1978. Revegetation program 1977 annual report. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1979. Revegetation program 1978 annual report. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1980. Modular development phase monitoring report 5. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1981a. Modular development phase monitoring report 7, December 1979 - November 1980. Gulf Oil Corp. and Standard Oil Co. (Indiana).

_____ 1981b. Modular development phase monitoring report 8, December 1980 - May 1981. Gulf Oil Corp. and Standard Oil Co. (Indiana).

SECTION 7

SUMMARY

7.0 INTRODUCTION

The United States Department of the Interior/Geological Survey (USGS) initiated planning in 1969 for a prototype oil shale leasing program. Under this program, Gulf Oil Corporation and Standard Oil Company (Indiana) acquired the rights to Federal Oil Shale Lease Tract C-a in the Piceance Basin in northwest Colorado in 1974. These two companies are developing Tract C-a under a general partnership called the Rio Blanco Oil Shale Company (RBOSC).

RBOSC has been engaged in extensive environmental data collection programs since its inception in 1974. Environmental baseline data were gathered between October 1974 and September 1976. An interim environmental monitoring program was conducted between September 1976 and August 1977, the period during which the Tract C-a lease was suspended. RBOSC initiated the Modular Development Phase (MDP) of tract development and the MDP Environmental Monitoring Program in August of 1977.

The MDP Environmental Monitoring Program is designed to provide data on air quality, meteorology, visibility, terrestrial ecology, aquatic ecology, hydrology, and specialized topics including ecological interrelationships. The program is designed based on the environmental stipulations in the Tract C-a lease, analysis of baseline and interim monitoring data, assessment of probable development impacts, and inputs from the Minerals Management Service Oil Shale Office (OSO). Monitoring is conducted according to the MDP Environmental Monitoring Program Scope of Work (SOW), the current version of which (Revision 6.1) is dated February 25, 1981 and was approved by the OSO May 1, 1981, with four conditions of approval.

Data collected through the MDP Environmental Monitoring Program are reported semi-annually, in a mid-year and a year-end report to the OSO. The first MDP monitoring report (Modular Development Phase Environmental Monitoring Report One or MDP 1) was published in February 1978. Subsequent reports were published in September 1978, March and August 1979, March and August 1980, and March and August 1981. This section summarizes the ninth MDP Monitoring Report, which covers the 1981 reporting year (December 1, 1980-December 31, 1981). The report contains presentations and summaries of 1981 reporting year data; statistical comparisons between seasons, years, and locations; and assessment

of any development-related impacts. Sections of the report generally address objectives, methods, results and discussion, and summary and conclusions. Methods are referenced rather than fully described unless they are different from those employed in previous monitoring periods, need clarification, or have not been previously reported.

7.1 AIR STUDIES

Both air quality and meteorological data were collected during the reporting period. The major event affecting air quality within this period was the burning of Retort 1 from June to December. The maximum concentration of SO_2 (the major air pollutant of concern released from the retort) measured during the burn was 0.047 ppm at Site 1. Since this SO_2 concentration was measured under easterly winds (which would transport the stack emissions in the direction of Site 1), it is quite likely that this measurement resulted from the Retort 1 burn. Apparently, SO_2 emissions from the retort are not transported into Corral Gulch, because no values of SO_2 above the background level were detected at Site 3 during the Retort 1 burn.

A supplementary SO_2 monitoring program using grab bag samples was carried out during October, when emissions from the retort were temporarily diverted from the emissions control system to the flare stack. (A detailed report of this program is given in Section 6.7). The highest SO_2 concentration measured during this supplementary monitoring was 0.12 ppm (260 μ/m^3). This is one-half of the 3-hr Class II increment, but is not directly comparable because this was an instantaneous grab bag sample. SO_2 concentrations at the same location were 40 percent of this value an hour earlier, and near background levels an hour later.

The ozone concentrations found in the vicinity of the tract varied from 0.001 to 0.073 ppm, well below the National Ambient Air Quality Standard (NAAQS) for ozone of 0.12 ppm. The diurnal cycle of ozone concentrations at Site 3 was greater than at Site 1. The larger cycle at Site 3 results from nighttime inversions which develop within the gulch in which Site 3 is located. The inversions effectively seal off the gulch from exchange with the rest of the atmospheric boundary layer, allowing ozone destruction reactions to reduce the ambient ozone concentrations at night.

The source of the relatively high ozone concentrations measured at the tract has not been definitely identified, although these concentrations have been found to be typical of many other remote locations. There has been no evidence of local photochemical production from either natural or anthropogenic sources.

Total suspended particulates (TSP) did not exceed the NAAQS during the current year. Multiple and stepwise regression analyses were carried out on the parti- culate data, using a combination of meteorological and site activity variables. The highest correlations were found using the annual rather than the seasonal TSP data sets. Approximately two-thirds of the variability of TSP concentrations in the annual data sets could be explained by the meteorological and site activity variables. This is very similar to the results of regression analyses performed for the three previous years.

Site activity parameters ranked no higher than third in explaining the variability of TSP concentrations, and contributed only minor improvements to the regression analyses. Temperature was by far the most successful predictor, largely because it has an annual cycle similar to the TSP data, and it serves as an indicator variable for other important parameters, such as soil moisture.

Review of the meteorological data from the current year revealed that 1981 was slightly warmer and considerably wetter than previous years. Precipitation at the tract totalled approximately 17 inches during the current year. The annual temperature range of 50 C (-20 C to +30 C) measured during the current year at Site 1 is typical of continental sites. Wind speed at the tract has been relatively low, reaching a maximum of 26 mph at the 10-m level at Site 1. Winds have been predominantly out of the west and southwest.

The 1981 visibility monitoring program indicated a slight increase in visual ranges in the Piceance Creek Basin. The mean annual visual range during 1981 was 86 miles, which compares with visual ranges of 85 miles measured in 1980, and 79 and 80 miles measured during the three earlier years of monitoring. There is a large day-to-day variability in the visual range, but this is primarily a result of widely varying meteorological conditions. The maximum visual range measured in 1981, 175 miles, was the second highest value in the five years of monitoring. Visual ranges of at least 142 miles have been recorded during each of the years. These values approach the theoretical limit of visual range in the atmosphere.

Two noise surveys were taken during the reporting period. The measured sound levels generally ranged from less than 30 dBA (the threshold of the instrument) to 50 dBA, except near the main construction area (adjacent to the headframe), which averaged 67 dBA. If the measurements taken near the main construction area are excluded, these sound levels are comparable to data taken during the baseline period.

7.2 TERRESTRIAL STUDIES

The components of the Terrestrial Monitoring Program examined during the 1981 reporting period include vegetation type mapping and stress, browse condition and utilization, phytosociology, range production and utilization, small mammal, avifauna, mule deer, and feral horse studies.

The distribution of plant communities during 1981 was compared with that established during baseline studies and as a result of analysis of 1978 color aerial photographs. Changes noted on Tract C-a and within a five mile perimeter are the result of oil and gas exploration as well as Tract C-a related construction including the airstrip, the road to off-tract property, coreholes, and the dewatering/reinjection system. Small amounts of Pinyon-Juniper and sagebrush vegetation have been affected by these activities but no major changes in plant community distribution have resulted from activities other than construction related to Tract C-a development. Analysis of 1981 color infrared photographs is not complete; consequently, results will be reported in subsequent MDP Monitoring Reports

Browse studies indicated that the weighted average percent utilization ranged from 5 percent in the sagebrush to 9 percent in the Pinyon-Juniper vegetation type. Utilization increased in the Mixed Brush and sagebrush types but decreased slightly in the Pinyon-Juniper habitat type relative to 1980 data. Results of a two-way ANOVA using arcsine transformed estimates of leader utilization among years (1978-1981) by individual browse species indicated significant differences ($\alpha \leqq 0.025$) in use of serviceberry (Amelanchier utahensis) within the Mixed Brush type; sagebrush (Artemisia tridentata), pinyon pine (Pinus edulis), bitterbrush (Purshia tridentata), mountain mahogany (Cercocarpus montanus), snowberry (Symphoricarpos oreophilus), and serviceberry within the Pinyon-Juniper type; and sagebrush within the sagebrush vegetation type. For the most part, all of these species experienced significantly lower browse leader usage in 1981 than during 1978. This lower leader use in 1981 relative to 1978 is probably a result of the decline in the mule deer herd due to the harsh 1978-79 winter.

Range condition ratings based on hedging class are for the most part an improvement over what was exhibited in 1980. These meliorations are due to lower browse utilization over the years. Because the RBOSC browse studies are designed to census the same shrubs every year, any large changes in range condition ratings based on hedging class would not be found. However, analyses of these data over years should show trends in range condition ratings.

Phytosociological studies were conducted within the Pinyon-Juniper and sagebrush vegetation types in Treatment Area 7, which is located just east of RBOSC's off-tract land. Average coverage of trees and shrubs within the Pinyon-Juniper habitat type was 44.2 percent. Pinyon pine (Pinus edulis) and juniper (Juniperus osteosperma) accounted for almost all of this cover. Sagebrush (Artemisia tridentata) had the highest average density (1,100 stems per hectare) of any tree or shrub surveyed in the Pinyon-Juniper area (density averaged 1,953 stems per hectare for woody species). Herbaceous coverage averaged 16 percent, with grasses accounting for 12.3 percent and forbs 3.7 percent of this total. Dominant grasses were bluegrass (Poa) and wheatgrass (Agropyron) species while Hood's phlox (Phlox hoodii) and Cryptantha sericea were the most prevalent forbs. Statistical comparisons of arcsine transformed coverage estimates for grasses and forbs showed no significant differences among transect within Area 7 ($\alpha \leq 0.05$).

Coverage of trees and shrubs in the sagebrush vegetation type averaged 22.3 percent while average density was 11,287 stems per hectare. Sagebrush was the most prominent species, averaging 20.5 percent cover and 9,573 stems per hectare. Douglas rabbitbrush (Chrysothamnus viscidiflorus) was a subordinate shrub, averaging 1,280 stems per hectare and 1.4 percent cover. The grass-forb stratum averaged 30 percent coverage. Grasses, primarily the bluegrass, wheatgrass, and needle-and-thread (Stipa comata) species, accounted for 21.7 percent of this total cover. Forb coverage was 8.4 percent most of which was made up by Hood's phlox and, to a lesser extent, scarlet globemallow (Sphaeralcea coccinea) and Cryptantha sericea. As in the Pinyon-Juniper discussion, there were no significant differences ($\alpha \leq 0.05$) for the arcsine transformed grass and forb coverage data in the sagebrush habitat type among transects within Area 7.

Range productivity and utilization studies indicated that production ranged from 106.6 kg/ha in the Pinyon-Juniper vegetation type to 440.8 kg/ha in the Mixed Brush type. With the exception of the Pinyon-Juniper type, forb production exceeded grass production. Wheatgrass (Agropyron) species, Indian ricegrass (Oryzopsis hymenoides) and bluegrass (Poa) species were the dominant grasses in all three vegetation types. For the most part, forb species responsible for the majority of the production were similar for all three habitat areas. Hood's phlox (Phlox hoodii), stemless goldenweed (Haplopappus acaulis), bastard toadflax (Comandra umbellatum), and sulfur eriogonum (Erigonum umbellatum) were predominant on the Mixed Brush area. The Pinyon-Juniper habitat type was dominated by Cryptantha sericea, stemless goldenweed, and Hood's phlox. The dominant forb species within the sagebrush vegetation type was Hood's phlox.

Statistical comparisons of range production among 1981 transects within the three vegetation types indicate significant differences ($\alpha \leqq 0.025$) for forb production within caged plots in the Pinyon-Juniper habitat type, and for grass and forb production within caged plots in the sagebrush vegetation type. Comparisons among years (1978-1981) using a two-way ANOVA indicate significant differences in grass production for caged and uncaged plots in all three vegetation types. An exception was grass production within caged plots in the Mixed Brush habitat type. Grass production in 1981 was significantly greater than during 1978 in all of the vegetation types.

Utilization of the Mixed Brush and sagebrush vegetation types declined in 1981 when compared to previous years. Within the Mixed Brush type, usage declined from a three year high of 31 percent recorded in 1980 to 22 percent in 1981. Utilization in the sagebrush vegetation type decreased from 40 percent in 1980 to 32 percent in 1981. Utilization for the Pinyon-Juniper area could not be determined because of a higher total herbaceous production in uncaged than in caged plots. This appears to be due to an extremely inflated forb production caused by stemless goldenweed (Haplopappus acaulis) (176.8 g/m^2 (1,768 kg/ha) on one uncaged plot). If stemless goldenweed is excluded from the uncaged plots (it was not encountered on any caged plots), the total production in uncaged plots is lower than that for caged plots. The result is a 12 percent usage, which is comparable to use in the previous two years.

Small mammal trapping studies were conducted in 1981 in sagebrush and Pinyon-Juniper habitats in control and treatment study areas on and near Tract C-a. These studies are designed to determine the species presence and habitat affinity, and to provide indices of relative abundance of dominant small mammal species.

In 1981, the deer mouse (Peromyscus maniculatus) continued to be the most frequently captured species in all trapping locations. The least chipmunk (Eutamias minimus) continued to be the second most frequently captured species in Treatment Area 5 and Control Area 6. Other species captured in 1981 were the golden mantled squirrel, the pinyon mouse, and the sagebrush mole. The limited species diversity may be a function of habitat qualities, trap affinities of the various species, or a combination of both. Species diversity has remained rather stable in Area 5 and Area 6 for three years. The yearly variation in the number of captures of dominant species in Area 5 and Area 6 is within the expected range due to normal fluctuation in small mammal populations. The reason for the low capture rate for all species in Treatment Area 7 is unknown. Phytosociological differences do not appear to be great enough to account for the differences between the small mammal capture rate in Area 7 and those in Areas 5 and 6.

The objectives of the avifauna program are to determine the presence, habitat affinity, relative density (number observed per hectare of habitat), and relative abundance of avifauna species in sagebrush and Pinyon-Juniper habitats within control and treatment areas.

Avifauna sightings have changed little since initiation of sampling in 1979. Not all species are observed in all years. Most of the species seen infrequently are not abundant in the region and/or are not common to the habitat types being surveyed.

Species indicative of the Pinyon-Juniper habitat type are the Mountain Chickadee, Mountain Bluebird, and Black-throated Gray Warbler. Densities of these species have varied among the sample years, with the numbers of some species declining and others increasing. The Pinyon-Juniper habitats are somewhat dissimilar in the three areas in which avifauna are censused (see Section 3.1C

of this report). These dissimilarities may account, in part, for the different species observed in the three study areas. These differences are typical and expected when comparing geographic areas. Common species in the sagebrush habitat are the Green-tailed Towhee and Brewer's Sparrow. Overall densities of avifauna species in the sagebrush habitats are very similar among the study areas for the years sampled.

The high variability of avifauna populations from year to year precludes drawing any firm conclusions regarding the effect of tract development on avifauna.

The objectives of RBOSC's mule deer monitoring program are to obtain indices of mule deer density in a study area centered on Tract C-a, to compare those indices with those from CDOW Game Management Unit 22 and, if possible, to compare differences in mule deer densities within various portions of the study area.

The deer density estimates for 1981 and previous years show an overall decline in winter use of the study area since the counts were initiated in 1978. The Piceance Basin deer herd was fairly large in the fall of 1978, and the ensuing winter caused severe deer mortality. As much as one half of the deer herd, including 80-90 percent of the fawns born in 1978, was lost to starvation and exposure in the winter of 1978/79 (John Gray, CDOW, personal communication). Analyses of the mule deer density data collected to date indicate that populations are beginning to rebound from this low point, however. Analysis of winter density indices for the four years sampled to date reveals that, although average densities continued to decline in 1981, this decline was not statistically significant. Densities had declined significantly for two consecutive years prior to 1981.

Evidence that deer populations are increasing can be found by examinations of 1981 mule deer density data as well. Limited snow accumulation during the winter of 1980-81 allowed the deer to winter at elevations which were higher than normal, resulting in a reduction of use of the study area. Consequently, density estimates for 1981 may have been somewhat depressed. This theory is substantiated by the fact that winter density estimates were higher in 1981

than in 1980 in only three blocks within the study area: blocks 1, 4, and 7. These blocks are at higher elevations than the rest of the blocks and are near summer range. The regional deer population thus may have been higher than indicated by the 1981 indices.

Considering the effects of winter conditions on mule deer movements and overall herd stability, the impacts resulting from the development activity on Tract C-a to date on mule deer are difficult to assess. Continued data collection and scrutiny should yield more information on deer behavior in the western Piceance Basin, and increase the feasibility of identifying any development-related impacts.

The objective of the mule deer road kill survey is to determine mule deer mortality due to collisions with vehicles along Rio Blanco County Road 24, from the Piceance Creek Road to Tract C-a. Ten road kills were observed in 1981. Even though deer densities along County Road 24 varied greatly from 1979 to 1981, the number of road kills did not. It is likely that some deer road kills always will be associated with heavy traffic in areas of high deer density.

Feral horses occur on and in the vicinity of Tract C-a. The objective of the feral horse monitoring studies is to provide qualitative information concerning the status of feral horses in the RBOSC study area. Feral horses were counted from a helicopter in March 1981. Ten bands of horses totaling 57 individuals were observed. This number is less than the 99 horses observed in the 1979 count and the 120 observed in 1980. The BLM conducted horse roundups throughout the Piceance Basin in September of 1980. This is probably the reason for the reduction in the number of horses observed in March 1981. Another factor in the reduced count may have been the limited snow cover during the census period, which allowed the horses to move to higher elevations outside the study area. Foal success was determined by a road count survey separate from the aerial survey. Foal success was apparently similar for 1980 and 1981.

7.3 AQUATIC STUDIES

Physical parameters examined at each of the aquatic sampling stations indicate seasonal as well as annual variability. Few trends or major changes in the physical measurements could be detected from the data. Station CG-1 experienced an increase in flow as compared with baseline conditions.

Water quality measurements made in 1981 indicated no significant changes in White River water quality upstream from its confluence with Yellow Creek, except for a possible increase in TDS at Station WR-2 in October. Examination of the 1981 data for the stations on Corral Gulch and Yellow Creek indicates a general and substantial downstream increase in dissolved solids.

Annual variations in periphyton densities occur on a seasonal basis and are directly related to such highly variable environmental parameters as current velocity, temperature, light, spring runoff, turbidity and substrate type. The 1981 density estimates at Station CG-1 were lower than the baseline values, and changes in species composition indicate a slightly higher detrital load. Changes in species dominance over time at this site could be naturally induced since such changes are not uncommon in aquatic habitats like Corral Gulch, which exhibits a high degree of variability in environmental parameters.

Station YC-3 on Yellow Creek has spring and fall periphyton communities which appear to be dominated by a group of diatoms whose relative abundance varies annually. There has been an increasing summer trend of green algal dominance at Station YC-3 during the MDP monitoring studies from 1978 through 1981.

Station WR-1 on the White River, upstream from any project influence, has shown changes in periphyton density and species diversity similar to Station WR-2, which is on the White River downstream from the confluence of Yellow Creek. Therefore, it appears that Tract C-a project activities have little or no effect on the periphyton communities of the White River.

The macroinvertebrate fauna at Station CG-1 are characteristic of the fluctuating conditions common to small streams in semiarid regions. Station CG-1

is located in an unstable area characterized by changing flow and turbidity. As might be expected under such conditions, seasonal changes in macroinvertebrate densities occurred at this station in 1981. The low densities in July are probably attributable to the flash flood which occurred just prior to sampling. There was no discharge of water from project dewatering activities during 1981, so it is likely that other seasonal changes observed at the station in 1981 were due to natural causes.

Yellow Creek is a small creek also affected by natural fluctuations in hydraulic and water quality parameters. The upper Yellow Creek station, YC-1, showed similarities to Stations YC-2 and YC-3 on lower Yellow Creek have similar macroinvertebrate communities characterized by organisms tolerant of unstable flow and turbidity conditions.

The White River does not appear to have been directly affected by operations on Tract C-a. The macroinvertebrate communities at Station WR-1 and WR-2 can be described as normal for a western stream the size of the White River; however, they are substantially more diverse and stable than the communities of Corral Gulch and Yellow Creek.

7.4 HYDROLOGY STUDIES

The hydrology monitoring program collects information for several needs:

- Stipulations of the lease and conditions of approval from the OSO
- Engineering design input for mine and water handling systems
- Evaluation of the need for environmental mitigative measures
- Permit requirements

The program includes monitoring at numerous installations, including stream gaging stations, springs and seeps, erosion and sedimentation stations, alluvial and deep aquifer wells, surface impoundments, surface discharges, reinjection system, and dewatering wells. The natural hydrologic and hydrogeologic environment as well as facilities associated with tract development are monitored.

During 1981, the hydrology monitoring program was modified to focus on four proposed major development activities on Tract C-a (RBOSC 1981):

1. Dewatering/Reinjection/Discharge Program
2. MIS Modular Development Area
3. Open Pit
4. Lurgi Plant Site

The discussion of the 1981 monitoring program is divided into three sections, corresponding to above-listed items 1, 2, and 4. The development of the open pit and hence monitoring of this activity has been deferred and will not be considered in this report. The Lurgi plant site construction has also been deferred but some collection of background data was included in the 1981 monitoring effort and is considered in this report.

Hydrology monitoring stations have been classified as follows:

- Type I - control stations not expected to be influenced by a given set of development activities

- Type II - expected to exhibit direct, short-term impacts, should impacts result from development; such stations are located generally downgradient in near-field area relative to development

- Type III - expected to exhibit indirect or long-term impacts; should impacts result from development; such stations are located downgradient from development in far-field areas.

Grouping stations allows for spatial as well as temporal comparison of water quality and physical parameters. Thus "pre- and post" development levels and the "control vs potentially affected" areas can be compared.

A. Dewatering/Reinjection/Discharge Program

The dewatering/reinjection/discharge program focuses on monitoring for changes in ground water levels and surface flows. The cone of depression from the dewatering operation was relatively stable throughout 1981. Dewatering was accomplished through dewatering wells and mine sumps until late November 1981 when the use of dewatering wells was terminated. Dewatering flows were all reinjected or consumed in 1981; no water was discharged at the surface from this operation.

The mean concentrations of dissolved constituents in the composite reinjection water during 1981 were generally similar to that of 1979 and 1980. Decreased yearly maximum levels of calcium, magnesium, chloride, and sulfate were observed in 1981 relative to 1980.

Water quality monitoring for the dewatering/reinjection/discharge program focused on the upper aquifer. The mean concentrations of major inorganic parameters in upper aquifer control wells during 1981 were similar to 1980 means. However, mean levels of TDS, calcium, magnesium, bicarbonate, and

sulfate were lower in 1981 relative to 1980. Mean concentrations in near-field wells in 1981 were commonly higher than either 1980 or baseline (1976) means. Far-field mean concentrations in 1981 were similar to 1980 means for most constituents.

The MANOVA for selected upper aquifer water quality constituents indicated significant variability (at the .05 significance level) for all parameters except pH, fluoride, chloride, and bicarbonate for the area main effect. Significant variability for the year main effect was noted only for pH, magnesium, sodium, and marginally for chloride. The interaction term (area x year) was not significant for any constituents. This indicates a lack of change in the relative water quality at control, near-field, and far-field wells over time, although the variability among station types and years is highly significant for some constituents.

Duncan's Multiple Range Tests were used to examine the nature and significance of differences in mean concentrations over time (year) and space (control, near-field, and far-field) in the upper aquifer. Examination of spatial differences indicated that there were no significant differences between control and near-field means for conductivity, alkalinity, and sodium. There were no significant differences between near-field and far-field means for sodium. The analysis of means show the general increase in pH in the upper aquifer since the baseline and decrease in sodium and chloride concentrations. Recent years data have been very stable for these constituents. The changes in mean concentrations over time for magnesium and chloride are not significant.

The MANOVA related variance analyses, and the Duncan's Multiple Range Test indicated that although certain constituents vary significantly in time and space, the general pattern of water quality has not changed appreciably over time. Impact-related changes are not apparent from this analysis.

The water levels have been very uniform over the last two years of record for the lower aquifer, indicating an absence of influence from the continuing reinjection operations.

B. MIS Modular Development Area

Monitoring of the MIS Modular Development Area includes sampling of various process ponds, alluvial aquifers and deep aquifers. The focus of this sampling is on water quality.

The East Retention Pond is located adjacent to the MIS process area. Concentrations of most constituents in this pond increased appreciably in 1981 relative to 1980, a reflection of increased production activities in 1981. This is generally shown by increased conductivity from 1000-3000 micromhos/cm in the first half of 1981 to about 6000 micromhos/cm in the second half of the year. There was no discharge of this higher conductivity water.

The water quality of the eight evaporation ponds sampled during 1981 was quite variable due to variations in operations during 1981. Water was detected during 1981 in piezometers located adjacent to the evaporation ponds but the water quality data indicated that the water was probably due to precipitation rather than pond leakage.

The general water quality at alluvial control wells for the MIS monitoring program has been fairly constant since the baseline (1976). Most of the variabilty in mean concentrations is due to 1981 calcium and sulfate levels which increased relative to previous observations. Near-field alluvial wells are typically dry. Because these wells only intermittently contain water, resulting in different wells being sampled at different times, the water quality in the near-field is rather variable. Similarly, the water quality of the far-field data set has been variable in recent years. Temporal trends were not obvious in these data sets.

The concentrations for most major inorganic constituents in the MIS alluvial wells increased in the downstream direction. Typically, maximum concentrations in 1981 were observed at far-field stations. Calcium concentrations, however, were generally higher at near-field than at either far-field or control alluvial wells. This increasing trend in the downstream direction is typical for natural systems and hence no development-related effects are indicated.

The results of the alluvial aquifer MANOVA for selected water quality constituents indicated that, for most major inorganic constituents, significant variability was observed for the main effects of monitoring area or station type (control, near-field, far-field) and year. The interaction term (area x year) was significant only for TDS, pH, and sulfate. Thus, for most constituents, the spatial pattern of water quality variability has not changed significantly over time.

Duncan's Multiple Range Test results indicated that control area means were not significantly different than near-field alluvial well means for sodium and chloride. Near-field and far-field means were not significantly different for TDS, alkalinity, magnesium, chloride, bicarbonate, and sulfate. Thus, control alluvial well water quality tended to be significantly different than near-field and far-field wells.

Beyond an increasing trend in mean pH and perhaps sulfate concentrations, and a small decline in recent years in sodium concentrations, the 1981 means in the alluvial aquifers are not consistent with earlier observations. Most of the observed changes over time, though significant statistically, do not appear to be of great magnitude nor indicative of development-induced impacts on water quality of the alluvial system.

The mean levels of most water quality parameters for upper aquifer control wells for the MIS Area monitoring program in 1981 were somewhat lower than in 1980 and somewhat higher than baseline (1976) means. The general chemical composition of upper aquifer control stations has not changed appreciably since the baseline period.

The mean concentrations of major ions in 1980 in near-field upper aquifer wells were similar to means observed in 1980, however, the means for many ions were lower than basline (1976) values. A shift from sodium-bicarbonate to a mixed ion system is indicated. The 1981 far-field water quality was generally similar to 1980 observations.

In the upper aquifer wells monitored in 1981 for the MIS Area hydrology monitoring program, mean salinity generally decreased in the downgradient

direction (from control to near-field to far-field). This trend was mostly attributable to decreases in calcium, bicarbonate, and sulfate concentrations. No impact-related trends, such as increased concentrations in the near-field wells are apparent from these observations.

The results of the MANOVA for selected water quality constituents indicated that, for most major inorganic constituents in upper aquifer wells, significant variability is observed for the main effects of area (station type) and year. Significant variability over the MIS upper monitoring areas was observed for all tested consitutents except conductivity and sodium.

Duncan's Multiple Range Tests indicated that all three monitoring areas (station types: control, near-field, far-field) were significantly different for pH, calcium, bicarbonate, and sulfate. Control and far-field upper aquifer wells were significantly different for all constituents.

The examination of means indicated that the concentrations for control stations are generally greater than, or comparable to those for near-field and far-field wells. Exceptions to this generalization are pH and chloride concentrations, which generally increased in the downgradient direction.

The analysis also indicated an increasing trend in pH over time in the upper aquifer, and general decreases in alkalinity, sodium, fluoride, and chloride concentrations since the baseline measurements. The mean concentrations in recent years have been fairly stable, and development-related impacts are not evident.

Lower aquifer well GS-15L is included as a control station in the MIS Area hydrology monitoring program. The 1981 mean water levels, pH, and water temperature data were similar to observations for previous years. The 1981 mean TDS and alkalinity concentrations were appreciably greater than means observed in 1980. This was caused principally by increases in sodium and bicarbonate ion concentrations. These data reflect an increasing trend in concentrations of these constituents since the baseline period. The trend is probably related to upper-lower aquifer interconnections during the baseline period. The most recent data are more characteristic of lower aquifer water quality.

C. Lurgi Plant Site

The monitoring program for the Lurgi plant site was designed to monitor the hydrologic effects of the proposed Lurgi demonstration project facilities. Construction of this facility, to be located north of Tract C-a, has been delayed. Hence, hydrological data collection and analysis is currently oriented to defining the baseline or pre-development conditions in the plant site area streams, springs, alluvial aquifers, and deep aquifers.

Four spring and seep monitoring stations function as control stations for the Lurgi plant site. The mean concentrations of water quality parameters for these stations during 1981 were similar to 1980 observations. No appreciable temporal trends are indicated by these data.

The increased conductivity relative to earlier years that was indicated for the alluvial control well GS-S24 for 1981 was also reflected in the water chemistry data (no water chemistry data were collected at GS-S24 during 1980). Water quality during 1981 at near-field alluvial wells for the Lurgi plant site exhibited appreciable increases in mean total dissolved solids compared to earlier years (2051 mg/l versus 1379 and 1420 mg/l in 1977 and 1976, respectively). The change was due to moderate increases in most major ions and large increases in mean sulfate levels (923 mg/l in 1981 versus 594 and 597 mg/l in 1977 and 1976, respectively). Water chemistry was not monitored at these near-field stations during the 1978-1980 period. The mean concentrations of most major water quality parameters at the far-field alluvial wells decreased in 1981 as compared to 1980 (the only other year of record).

As expected, the concentrations of dissolved constituents in alluvial wells monitored for the Lurgi plant site program generally increased in the downgradient direction (control to near-field to far-field). The mean concentrations at near- and far-field alluvial wells were fairly similar during 1981, while concentrations at the control well were appreciably lower than either of the other two station groups.

The MANOVA of the Lurgi plant site alluvial aquifer monitoring data indicated significant variability for the area (station type) main effect for all of the selected constituents except fluoride. Significant variability for the year main effect was observed for all constituents but calcium, sodium, fluoride, and chloride. The interaction term (area x year) was nonsignificant for all constituents at the 0.05 level except TDS and conductivity and was only slightly significant for these two constituents.

Duncan's Multiple Range Tests for the area (station type) main effect showed two patterns. For TDS, conductivity, magnesium, bicarbonate, and sulfate ions, all three areas (control, near-field, and far-field) were significantly different. For pH, alkalinity, calcium, sodium, and chloride, the control and near-field groupings were not significantly different but were different from the far-field stations.

Most of the significant increases in means among the station groupings and over years are the result of 1981 sampling of the far-field stations (GS-S28, GS-S29, and GS-S30 well series) which exhibited appreciably higher levels of major inorganics than the near-field tract wells during the 1975-79 period.

The 1981 mean concentrations of most inorganic consitutents in upper aquifer control wells were slightly higher than 1980 means. Decreases in sodium and sulfate concentrations resulted in an overall decrease in the mean total dissolved solids level. The concentrations of all of these constituents except sodium have increased considerably since the baseline period (1976). To a large extent, this reflects the process of equilibration in deep aquifer wells rather than the effects of development activities.

Water quality data from sampling of near-field upper aquifer wells exhibited a general increase in concentrations of many major inorganic constituents in 1981 as compared to 1980. The increase was due largely to sodium, magnesium, and sulfate concentrations.

Mean concentrations of most constituents observed in 1981 at far-field upper aquifer wells were generally similar to or lower than 1980 mean concentrations. The concentrations observed in 1980 and 1981 were appreciably lower

than the means observed during the baseline (1976). The decline was exhibited mostly in concentrations of calcium, magnesium, bicarbonate, and sulfate.

No consistent spatial trends were apparent in the 1981 mean and maximum concentrations. The near-field upper aquifer wells exhibited the highest mean TDS due to relatively high alkalinity (bicarbonate) levels. However, the near-field wells had the lowest mean sulfate concentration during 1981. Concentrations of magnesium and sodium were fairly similar across the three types of wells, but calcium concentrations decreased along the control near-field far-field gradient.

The MANOVA of upper aquifer water quality data indicated significant variability for all constituents tested for the area (station type) main effect. The year main effect was significant for all constituents except calcium, magnesium, fluoride, and sulfate. The interaction term (area x year) was significant for TDS, conductivity, pH, calcium, bicarbonate, and sulfate.

Duncan's Multiple Range Tests for the area (station type) main effect showed that the near-field means were not significantly different from the control or far-field upper aquifer well means for TDS, conductivity, calcium, sodium, and fluoride.

An increasing trend in the downgradient direction for TDS, conductivity, pH, magnesium, sodium, flouride, and sulfate is shown by these data. Alkalinity (and bicarbonate) exhibited maximum means in the near-field wells. The TDS, sodium, and chloride means in the upper aquifer for 1978-81 are not significantly different nor are any of the yearly means for conductivity and bicarbonate. The increasing trend over time for pH and alkalinity is as observed for other upper aquifer monitoring elements.

7.5 SPECIAL STUDIES/ECOLOGICAL INTERRELATIONSHIPS

A. Experimental Revegetation on Surface Disturbed Sites

Experimental revegetation Plot R-1, located on a northwestern exposure, had average coverage over the 16 treatment combinations of 43.1 percent for all species encountered during 1981. Planted grasses, specifically wheatgrass (Agropyron) species and, to a lesser extent, green needlegrass (Stipa viridula), accounted for 49 percent of the total R-1 average. A statistical comparison of 1981 grass coverage data between treatment combinations exhibited no significant main or interaction effect differences ($\alpha \leq 0.05$). However, comparison of data over the five sampling years indicated that planted grass coverage was significantly higher in 1980 and 1981 than for the previous three years. The biomass of planted grasses averaged 599.1 kg/ha over the 16 treatment regimes. A comparison of 1981 biomass data exhibited no significant differences ($\alpha \leq 0.05$) for main or interaction effects. However, when data from 1981 and 1978 were compared, the production of planted grasses was significantly higher in 1981 than in 1978.

Planted forb coverage averaged 10.5 percent over the treatment combinations and was responsible for 24 percent of the total R-1 cover. The dominant forb species were Lewis flax (Linum lewisii), yellow sweetclover (Melilotus officinalis var. Madrid), and cicer milkvetch (Astragalus cicer var. Lutana). For the 1981 data, planted forb coverage was significantly higher ($\alpha \leq 0.05$) on the plots in Block 2 than on the other two blocks. Comparison of data over the sampling years indicated significantly higher planted forb coverage during 1980 and 1981 than in the other years. The biomass of planted forbs averaged 152.3 kg/ha over the 16 treatment regimes. The 1981 data did not exhibit any significant differences ($\alpha \leq 0.05$) when compared using a three-way ANOVA. However, there was significantly higher forb production in 1981 than what was encountered in 1978.

The higher planted grass and forb production in 1981 when compared to 1978 is probably due to an increase in moisture over the years. Data from the rain gauges at R-1 indicate that moisture has steadily risen from 4.83 in. in 1978 to 9.38 in. in 1981.

Coverage of planted shrubs averaged 2.7 percent, which was 6 percent of the total coverage. Rabbitbrush (Chrysothamnus nauseosus and C. viscidiflorus), and winterfat (Ceratoides lanata) were the most dominant planted shrub species. There were no statistical differences ($\alpha \leqq 0.05$) when the 1981 data was analyzed with a three-way ANOVA. Comparison of planted shrub coverage over sampling years exhibited significantly lower cover after one year's growth than that exhibited in subsequent years.

Experimental revegetation Plot R-2, established in 1975 on a southeasterly slope, had average cover of 30.1 percent for all species encountered during 1981. The planted grasses were responsible for 39.5 percent of this total and had average coverage of 11.9 percent. Wheatgrass species and Indian ricegrass (Oryzopsis hymenoides) were the dominant planted grasses, while green needlegrass was a common subordinate species. There were no significant differences among treatment regimes ($\alpha \leqq 0.05$) when the data collected in 1981 were analyzed, but there were significant differences when the planted grass cover data was compared among years. Planted grass coverage was significantly higher in 1980 than in 1981, both of which are significantly higher than any of the other three sampling years. Average planted grass biomass was 270.5 kg/ha and was primarily made up by those grass species with the highest coverage. No significant differences among treatment regimes ($\alpha \leqq 0.05$) were indicated by analyses of the 1981 biomass data. There were, however, significant differences when the data were compared among years. Production of planted grasses was significantly greater in 1981 than in 1978.

Coverage of planted forbs averaged 7.3 percent over the 16 treatment combinations and was responsible for 24.3 percent of the total R-2 coverage. The prominent forb species were Lewis flax and cicer milkvetch, with yellow sweetclover occurring as a subordinate forb. A statistical comparison of 1981 forb data exhibited no significant main or interaction effect differences ($\alpha \leqq 0.05$). When data from all years were analyzed, coverage of planted forbs in 1980 and 1981 was significantly higher than in previous years. These differences in forb coverage seem to be related to a block x mulch x fertilizer interaction effect with no corresponding main effect differences. Production of the planted forbs averaged 150.1 kg/ha. Most of this production consisted of Lewis flax, cicer milkvetch, and yellow sweet-

clover. When the 1981 planted forb biomass data were analyzed by the three-way ANOVA, no significant differences among treatment regimes ($\alpha \leq 0.05$) were noted. Significant differences did arise when data for 1978 and 1981 were compared. Planted forb biomass was significantly greater in 1981 than in 1978.

Planted shrub coverage accounted for 18.6 percent of the R-2 total with average cover over the different treatment combinations of 5.6 percent. The two rabbitbrush species and winterfat were the dominant planted shrub species. Based on 1981 data, no significant main or interaction effect differences were noted. However, a comparison of data over the five sampling years exhibited significantly higher coverage in 1980 and 1981 than in the previous three sampling years. These differences may be attributed to differences in the mulch treatments as well as significant block x mulch interaction effects. Plots that were hydromulched had significantly greater shrub coverage than plots with the other three mulch treatments (no mulch, crimped straw, and straw covered with netting).

The total biomass on Plot R-2 for the clipped grass and forb species averaged 492.1 kg/ha. The planted grasses were responsible for 55 percent of the total compared to 30.5 percent for the planted forbs.

A comparison between data from Plots R-1 and R-2 and data from the neighboring, undisturbed sagebrush community revealed that production on these revegetation plots exceeded that of the sagebrush plant community. Herbaceous production averaged 435.3 kg/ha during 1981 along the sagebrush production transects, compared to 831.0 kg/ha for Plot R-1 and 492.1 kg/ha for Plot R-2.

B. Experimental Revegetation on a Simulated Processed Shale Disposal Site

Coverage averaged over all treatment combinations for species present on Plot R-3 during 1981 was 37.5 percent on the treatment portion (underlain by processed shale) and 38.4 percent on the control portion (not underlain by processed shale). The highest coverage on the treatment portion was recorded on the hay mulch/low seeding combination, while the lowest coverage was found

on the no mulch/low seeding combination. On the control portion, the highest coverage was found on the hay mulch/high seeding combination; the lowest coverage was obtained on the no mulch/low seeding combination.

The prominent planted grass species encountered on both the control and treatment portions of Plot R-3 were wheatgrass species and Indian ricegrass. The most prevalent invading grass species were cheatgrass (Bromus tectorum) and crested wheatgrass (Agropyron cristatum). Coverage of all planted grasses averaged 21.4 and 24.0 percent on control and treatment portions, respectively. A comparison of 1981 coverage data for all planted and invaded grasses indicated that significant differences ($\alpha \leqq 0.05$ and 0.025 for plant and invaded species, respectively) exist among the various seeding regimes, but not among fertilizer treatments or between shale-no shale substrates. Planted grass cover was significantly higher on areas seeded at 28 kg/ha than those seeded at 17 kg/ha. Invading grasses exhibited significantly higher coverage on plots seeded at the lowest rate (17 kg/ha) than plots seeded at either the medium (22 kg/ha) or the high (28 kg/ha) seeding rate.

Planted grass coverage on Plot R-3 was highest during 1979 and has decreased slightly since that time. The decreased coverage noted during 1980 and 1981 is a result of sampling aboveground biomass during the 1979 season via destructive techniques (coverage estimates in subsequent years were made on the same quadrats upon which biomass was measured in 1979). Data for 1980 and 1981 indicate that planted grasses recover quickly from the impact of destructive sampling, which simulates heavy grazing pressure. However, the coverage of planted grasses the second year after destructive sampling is still significantly lower ($\alpha \leqq 0.05$) than that recorded in 1979. Furthermore, concomitant with reduced coverage of planted species, coverage of invaded grasses was significantly higher ($\alpha \leqq 0.05$) in 1980 than during any other sample period.

Planted forb coverage values averaged over all treatment combinations within control and treatment portions of Plot R-3 were 8.9 and 5.7 percent, respectively. The highest coverage of planted forbs on both the control and treatment portions of Plot R-3 was recorded on areas which were hydromulched and seeded at 17 kg/ha (the lowest rate). Cicer milkvetch was the dominant forb throughout Plot R-3; however, Lewis flax and yellow sweetclover were subordinate forbs

commonly occurring on both the control and treatment portions of the site. A comparison of 1981 coverage data for all planted and invaded grasses indicated that there were no significant differences ($\alpha \leq 0.05$) in coverage based on any of the treatments tested.

Planted forb coverage has increased subsequent to clipping quadrats for biomass determinations in 1979 (3.5 percent in 1979; 7.3 percent in 1981). This increase may be related to decreased competition from grass species. Statistical comparisons of forb coverage data among years indicate that 1981 coverage, though similar to that for 1980, was significantly higher ($\alpha \leq 0.05$) than that recorded for 1977, 1978, or 1979.

Planted shrub coverage averaged 4.2 and 4.6 percent on control and treatment portions of R-3, respectively. The greatest planted shrub coverage on the control portions was found on plots which were seeded at 22 kg/ha and hydromulched, whereas the seeding rate of 28 kg/ha followed by hydromulching resulted in the highest planted shrub coverage on the treatment portion of the study site. Winterfat and fourwing saltbush (Atriplex canescens) were the dominant planted shrub species. Broom snakeweed (Gutierrezia sarothrae) was the most common invading shrub species encountered on both the control and treatment areas. A comparison of total shrub coverage among all treatment combinations for 1981 showed no significant differences ($\alpha \leq 0.05$) based on substrate, mulch, or seeding rate treatments.

Coverage of planted shrub species on the quadrats sampled declined from a high of 16.7 percent in 1979 to 4.4 percent in 1981. Coverage recorded during 1981, 1980, 1978, and 1977 is significantly lower ($\alpha \leq 0.05$) than that noted for 1979. Because shrub species are not expected to readily produce growth from rootstocks as do many grasses and forbs, the planted shrubs on Plot R-3 did not recover from destructive sampling conducted in 1979 as well as the grass and forb species.

No significant differences ($\alpha \leq 0.05$) between electrical conductivity (EC) in soils from control and treatment portions of the study site were noted during 1981. As expected, EC increased with depth in the reconstructed soil profiles on both the control and treatment sides of R-3, probably as a result of the

increased amount of unweathered parent material. Electrical conductivity data suggest that the rubblized overburden materials within the reconstructed soil profile are continuing to prevent capillary migration of dissolved salts from the processed shale into the surface growth medium.

C. Experimental Revegetation Greenhouse Studies

Greenhouse studies were undertaken to assess the revegetation potential of Lurgi processed shale. The objectives of the studies were (1) to determine the concentrations of boron (B), molybdenum (Mo), fluorine (F), arsenic (As) and selenium (Se) in plants grown in Lurgi processed shale, as well as in various depths of topsoil and subsoil over the Lurgi processed shale; (2) to determine plant growth and response in various growth mediums, using techniques including biomass measurements of roots and shoots; (3) to investigate the suitability of Lurgi processed shale as a medium for seed germination; and (4) to assess the potential of stockpiled Tract C-a topsoils to infect roots with beneficial vesicular-arbuscular mycorrhizal fungi.

Five plant species (five replicates per species) were grown for six months within 11 variations of topsoil, subsoil and/or capillary barrier depths over Lurgi processed shale. The treatments, including two topsoil controls and one shale only treatment, were as follows:

1. 15 cm topsoil (control)
2. 30 cm topsoil (control)
3. 15 cm shale
4. 15 cm topsoil, 15 cm shale
5. 15 cm topsoil, 15 cm subsoil barrier, 15 cm shale
6. 15 cm topsoil, 30 cm subsoil barrier, 15 cm shale
7. 30 cm topsoil, 15 cm shale
8. 30 cm topsoil, 15 cm subsoil barrier, 15 cm shale
9. 30 cm topsoil, 30 cm subsoil barrier, 15 cm shale
10. 15 cm topsoil, 15 cm gravel barrier, 15 cm shale
11. 15 cm topsoil, 30 cm gravel barrier, 15 cm shale

The differential response of plants grown in the various treatments showed that growth in 30 cm of topsoil was superior to that in only 15 cm of topsoil. Adding an additional layer of subsoil below the topsoil improved plant growth. The use of pea gravel as a capillary barrier did not result in significantly better growth than that recorded for the 15 cm topsoil control ($\alpha \leqq 0.05$). The Lurgi shale underlying the various topsoil/subsoil growth mediums did not appear to hinder plant growth. Average aboveground production was nearly indentical among the five species tested. Furthermore, there was no significant difference in root biomass among the treatments.

The migration of boron, molybdenum, and fluoride from the processed shale into the overlying soils did not appear to occur under the conditions of this study. In fact, there appeared to be losses of the water soluble B, Mo and F from the topsoil/subsoil growth mediums due to leaching. A reduction in electrical conductivity indicated that leaching of salts from the surface growth mediums also occurred. The Lurgi process appears to cause a reduction in the availability of B and Mo in comparison to the TOSCO and U.S. Bureau of Mines processes. The uptake of B by plants was not significantly different ($\alpha \leqq 0.05$) among any of the treatments and topsoil controls. The B levels recorded were well within the tolerable levels for plant growth and animal uptake. Molybdenum also occurred in relatively low values in plants grown under all treatment conditions. However, the Mo content was significantly higher ($\alpha \leqq 0.05$) in plants grown in the shale-only as well as 15 cm topsoil over shale treatments when compared with topsoil controls (15 and 30 cm topsoil only). The fluorine content of plants grown in straight Lurgi processed shale reached high levels. The fluorine content dropped drastically, however, when only 15 cm of topsoil was placed over the shale. Similarly, the Se level in plants grown in straight shale was very high, but was reduced greatly with an application of 15 cm of topsoil over the shale. The low levels of arsenic measured in all plants and treatment profiles analyzed appear to offer no potential hazards to plant growth or for grazing animals.

Seed germination for the 12 species tested was very poor in or on Lurgi processed shale. The three germination treatments (surface, 1 cm and 2.5 cm)

were not significantly different; however, all three exhibited significantly lower ($\alpha \leq 0.05$) germination than that recorded on topsoil controls.

Under greenhouse conditions, the five test species grown in the topsoil/subsoil surface growth media from Tract C-a were found to be naturally inoculated with vesicular-arbuscular mycorrhizal fungi (VAM). Underlying shales and/or a capillary barrier had no discernible impact on VAM propagation in the Tract C-a topsoils.

D. Toxicology

Extensive toxicological and industrial hygiene studies are being conducted by the U.S. Department of Energy (DOE) Oil Shale Task Force and RBOSC on the products and by-products of MIS and Lurgi oil shale retorting. These studies are designed to characterize the physical and chemical properties, to determine biological activities, and to assess potential worker exposure and environmental hazards of oil shale process materials.

Preliminary results of the DOE research on MIS Retort Zero indicate that the sour water was more dilute than process waters for other in situ retorts. The crude shale oil, on the other hand, contained more sulfur than other shale oils. Analyses of the off-gases indicated that mercury and nitrogen oxide concentrations generally increased as the burn progressed. Testing of stack particulates demonstrate that most of the particulate organic material consisted of polycyclic aromatic hydrocarbons. Analyses of soil samples showed that there are significant differences in natural background concentrations of mercury among different soil types.

Sampling of hydrogen sulfide and dust conducted during the Retort Zero burn indicated that the Threshold Limit Values for 8-hr exposures to hydrogen sulfide and dust were not exceeded. Additional data on the DOE toxicological and other DOE-sponsored studies will be available in the near future.

Screening tests were conducted to determine the toxicity and mutagenicity of various MIS generated materials. Toxicity tests using a bioluminescent strain of bacteria and the test organisms indicated some toxicity associated

with certain MIS sour waters. Both the Ames and sister chromatid exchange tests of MIS shale oil yielded positive results for mutagenic activity.

RBOSC-sponsored toxicology tests conducted by IIT Research Institute are presently underway for both MIS and Lurgi-generated materials. The battery of tests include acute toxicity tests, tests to evaluate dermal and ocular irritation, and genetic assays such as the Ames Test, forward mutation assay and dermal cytogenetics tests. These tests are scheduled to be completed in 1982.

E. Run-Of-Mine Lysimeter

RBOSC, in cooperation with the EPA, the USGS, and the DOE Task Force, is conducting leaching studies on stockpiled run-of-mine ore in order to determine the chemical characteristics of leachate generated from raw shale in the field and to compare these results with those from laboratory tests on the same materials. This comparison is being conducted to determine the importance of such factors as percolation rates (residence time), wetting and drying cycles, and other weathering factors on leachate quality.

The field lysimeter tests were initiated in mid-June, 1980. The results of the tests, both leachate volumes and chemical analyses, were published in a First Annual Progress Report for the period April 1, 1980 - May 31, 1981, by Dr. David McWhorter (1981). A summary of this report was included in MDP 8. Since May 3, 1981, additional samples have been collected and analyzed. The lysimeters have been monitored only for volume (no sampling) since November 1981. Publication of a second annual progress report is expected in the Spring of 1982. The relevant portions of the forthcoming report will be included in the next MDP monitoring report.

F. Mule Deer Habitat Modification

During RBOSC's commercial operation, disturbances of the land will result in the loss of forage for wildlife, primarily mule deer. One means of mitigating these losses is to increase the mule deer carrying capacity of undisturbed areas to maintain the overall carrying capacity at, or near, predevelopment levels. RBOSC initiated an experiment in 1980 to determine the feasibility

of producing such increases in carrying capacity using habitat modification techniques.

The habitat modification experiment was designed to evaluate the effects of several factors critical to increasing deer carrying capacity: (1) snow depth, (2) moisture availability during the growing season, (3) selective brush removal, (4) quality forage, and (5) fertilization. Four 5-m corridors were chopped in each of two treatment areas, such that a differential accumulation of snow should occur between the two areas, thereby enabling an evaluation of the effects of such accumulation on forage production and utilization as well as deer movement. Half of each treatment area was seeded and fertilized with ammonium nitrate. Eight treatment regimes were thereby established. Control areas were also established in undisturbed sagebrush adjacent to each of the treatment areas.

Twelve permanent vegetation transects were established (four in each treatment area and two in each control area). Density of shrub species, percent cover of shrub species, and percent cover of herbaceous species were estimated within eight plots on each transect.

Significantly higher cover estimates and greater densities, as indicated by t-tests, were noted on corridors oriented parallel to the prevailing winds than on corridors oriented perpendicular to the wind. Additional analyses using three-way ANOVA's showed that the corridors oriented parallel to the wind had significantly higher cover on fertilized areas (ammonium nitrate applied at 120 pounds per acre) than on areas which received no fertilizer. Significantly higher densities were recorded on the areas which had been rotochopped as compared to those which were not chopped. No significant differences in cover or density, as based on the treatments tested, were noted on the study site oriented perpendicular to the wind. Assessments in subsequent years will be necessary before definitive trends in cover and density can be identified.

G. Shrub Growth Enhancement on a Simulated Mine Site and/or Disposal Pile Bench

A simulated mine site/disposal pile bench was constructed on Tract C-a in early 1982. The simulated bench is designed principally to evaluate the effects of water harvesting techniques on shrub growth. In addition, the effects of artificial irrigation, topsoil depth, and grazing are to be evaluated. The bench is designed to concentrate available moisture in certain areas, using water bars and variations in slope. Various combinations of fencing and topsoil applications will also be tested. Shrubs will be planted in each of the resulting treatment areas in the spring of 1982. Shrub growth will be evaluated on a yearly basis, to identify any effects of the various treatments on shrub growth. The success of the water harvesting techniques will be evaluated by periodic measurements of soil moisture content at fixed locations. The results of these evaluations will be included in subsequent MDP Environmental Monitoring Reports.

H. Range Exclosure

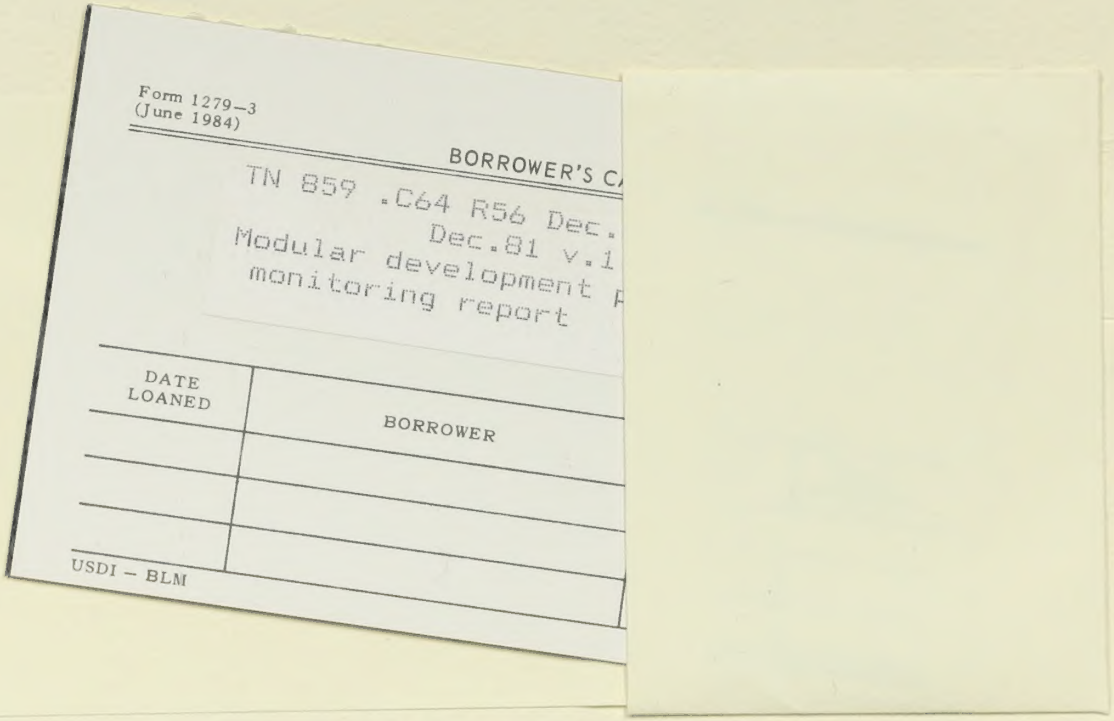
The range exclosure, located on Airplane Ridge near the western boundary of Tract C-a, had an average cover of 6.6 percent for the four compartments. Compartment B had a high herbaceous coverage of 9.17 percent, whereas the lowest herbaceous species coverage values were 6.92 and 5.64 percent, on compartments A and C, respectively. Grasses, primarily the wheatgrass, bluegrass (Poa), and Indian ricegrass species, accounted for the majority of the coverage on the four compartments. The predominant forbs were lobeleaf groundsel (Senecio multilobatus) for compartments A and B, northern sweet-vetch (Hedysarum boreale) for Area C, and scarlet globemallow (Sphaeralcea coccinea) for compartment D. The statistical analyses comparing herbaceous coverage between compartments exhibited no significant differences ($\alpha \leqq 0.05$).

Average biomass for the range exclosure was 130.79 kg/ha. Production values were 89.99, 197.31, 146.72, and 89.13 kg/ha for compartments A, B, C, and D, respectively. The predominant grass and forb species responsible for most of the herbaceous coverage also made up most of the herbaceous biomass. The

statistical comparison for 1981 biomass data between the four compartments exhibited no significant differences ($\alpha \leq 0.05$) for either grasses or forbs.

I. Supplementary Sulfur Dioxide Monitoring Program

The supplemental sulfur dioxide monitoring program showed no concentrations approaching either the NAAQS or PSD Class II increments. The highest impacts were very transitory and showed a great deal of variability both in time and space, sometimes occurring in Corral Gulch and sometimes on higher ground near Site 1. The highest concentrations were found near the west boundary of the tract, with decreasing concentrations on higher ground further to the west. Elevated concentrations found simultaneously at Site 1 and in Corral Gulch suggest that the plume is widely dispersed at least part of the time.


Form 1279–3
(June 1984)
BORROWER'S CA
TN 859 .C64 R56 Dec.
Dec.81 v.1
Modular development p
monitoring report
DATE LOANED
BORROWER
USDI – BLM